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ANNUAL REPORT

OF THE

SECRETARY OF WAR

FOR

THE YEAR 1878.

VOLUME II.

PART II.

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APPENDIX W.

TRANSPORTATION ROUTES TO THE SEABOARD.

W 1.

PORTION OF THE THIRD SUBDIVISION OF THE MISSISSIPPI TRANSPORTATION ROUTE (FROM CAIRO TO NEW ORLEANS).

OFFICE OF THE CHIEF OF ENGINEERS,
Washington, D. C., June 7, 1878.

SIR: I beg leave to submit herewith a copy of a report from Maj. Charles R. Suter, Corps of Engineers, dated May 27 last, just received at this office.

This report is a continuation of that made by Major Suter, February 18, 1875 (Ex. Doc. No. 19, part 7, Senate, Forty-third Congress, second session), under the appropriation for surveys for Transportation Routes to the Seaboard, in which he presented the results of his reconnaissance of the Mississippi River from Cairo to the mouth of Red River, showing the number, location, extent, and character of the bars needing improvement in the low stage of the river, and submitted a general project for their amelioration.

From this reconnaissance it appears that these so-called bars exceed 35 in number, that they vary in length from 5 to 12 miles, and that the length of river-bed to be improved will exceed 300 miles.

The present report continues the investigation into the character of these bars and presents a new class of proofs that they are the more elevated portions of the Tertiary clays and gravels that cross the course of the river. The current, even in the flood stage of the river, is unable to cut through them and therefore erodes the banks, which are chiefly alluvial, and the width of the river is thereby constantly increased. This constant increase of width reduces the mean low-water depth and shoals the low-water channels. Hence the importance of an early appropriation adequate to the commencement of the work of improvement. Major Suter submitted an estimate for this object, February 18, 1875, of $275,000, which is earnestly recommended.

Very respectfully, your obedient servant,
A. A. HUMPHREYS,
Brig. Gen. and Chief of Engineers.

Hon. GEO. W. MCCRARY,
Secretary of War.

SUPPLEMENTARY REPORT OF MAJOR CHARLES R. SUTER, CORPS OF ENGINEERS.

UNITED STATES ENGINEER OFFICE,
Saint Louis, Mo., May 27, 1878.

GENERAL: In my report of February 18, 1875, upon the portion of the third subdivision of the Mississippi transportation route, lying between Cairo and New Orleans, published with your annual report for 1875, page 496, great stress was laid upon the fact, which had been ascertained, that at all points of difficult navigation the river was found to be of abnormal width and the bed was largely composed of gravel. Of course the unyielding nature of such a bottom would render an increased width a necessity, for, the vertical scour being checked, lateral erosion could alone keep up the normal section.

The main point of interest was, therefore, to account for the presence of the gravel, which must of course be an item of great importance in any scheme for the improvement of the river, for if gravel in such large quantities is now moved by the current the difficulty of executing a successful improvement would be very greatly increased. I was never myself of the opinion that such was the case, for although large quantities of gravel are undoubtedly moved by the river when in flood, as shown by the growth of gravel-bars on heads of islands, under the lee of points, and in the chutes and high-water channels generally, yet the vast accumulations at a comparatively small number of localities pointed strongly to some local source from which the gravel was derived. Where shoals occurred in the neighborhood of the river bluffs it was of course sufficiently obvious that the washings from the bluffs, which contain much gravel, might account for the peculiar character of the shoals lying below them; but I was puzzled to account for the fact when no bluffs existed as an obvious source of supply.

In this dilemma I ventured in my report to put forward an hypothesis to account for the facts which did not even then seem entirely satisfactory to me. Since writing that report I have obtained additional information bearing upon the subject, which I think covers the whole ground. It is known that throughout the delta region there occur many isolated patches and ridges of a formation older than the alluvial, which seems to be analogous if not identical in character with the more conspicuous river bluffs. This formation frequently comes to the river-bank, and in some known instances crosses it. On the map of the delta region of the Mississippi, published with the report on the "Physics and Hydraulics of the Mississippi River," the fact that land of this formation is often above overflow has caused several of these points to be shown; but there are a good many others which are not shown, the banks being below high-water mark, and doubtless more careful examinations would considerably increase the number. The fact that some of these ridges are known to cross the river renders it in the highest degree probable that at the other points where this formation exists on one bank it may extend either wholly or partly across the stream. It is easy to understand that the result of the action of the river in crossing a bed of this material would be to sift out the lighter portions, leaving the heavier ones behind, and these solid bars would yearly acquire greater solidity by catching and retaining such heavy materials as might be moving along the bed of the river. This view accords well with the observed fact that at such places the width of the river is very much above the average and has greatly increased within a comparatively short period. Taking only into consideration the shoals above Red River, where less than 5 feet depth at low water has been recorded, the facts are as follows:

PHILLIPS BAR.

(57 miles below Cairo.)

The shoal here may be due to Hickman Bluffs above, or with more probability to an outlying portion of the ridge which is known to cross the river a few miles below here in the vicinity of New Madrid.

POINT PLEASANT.

(87 miles from Cairo.)

This bar is situated on the ridge above mentioned, and is undoubtedly caused by it.

PLUM POINT AND OSCEOLA.

(From 157 to 170 miles below Cairo.)

This long section of shoal river would be covered by an extension of the First Chickasaw Bluffs. The appearance of the bluffs themselves, and the direction in which high ridges are known to exist in the Saint Francis Bottom, render it almost certain that the bluff formation extends across the river here.

REEVES BAR.

(259 miles below Cairo.)

This bar lies at the foot of President's Island, just below Memphis. The bed of the river is of gravel from bank to bank, and it is probable that it crosses an extension of the bluff formation (Fourth Chickasaw).

SHIP ISLAND, SHOO FLY, HELENA.

(From 311 to 329 miles below Cairo.)

These shoals are all due, in my opinion, to the same cause, viz, the crossing of a ridge, which, known as Crowley's Ridge, apparently ends at Helena, but is supposed to be connected with a ridge of high ground running through the Yazoo Bottom. At any rate the banks at Shoo Fly Bar are the same on both sides of the river, and similar in formation to the bank at New Madrid. It is probable that this ridge extends down stream far enough to account for the shoals at Montezuma, 334 miles from Cairo.

CHOCTAW BEND.

(460 miles from Cairo.)

At this point the ridge above overflow, lying south of the Arkansas River, comes to the bank of the Mississippi. A heavy bed of gravel about 10 feet below high water is found on the head of Choctaw Island, No. 78, and also near the head of the bend above (Cypress Bend). It is also found on Catfish Towhead and in all probability extends across Catfish Point and consequently across Choctaw Bend.

ISLAND NUMBER 93 AND LAKE PROVIDENCE.

(564 to 572 miles from Cairo.)

The extensive shoals in this section are still unaccounted for, but the fact that the bed of the stream is covered with immense masses of gravel leads me to think that the Mississippi here also crosses a ridge or island of the old formation which has been so far washed away as not to show plainly along the banks. A few borings back from the bank would settle the question.

NATCHEZ ISLAND.

(760 miles from Cairo.)

This bar, which is only traditional, was probably caused by the Natchez Bluffs just above here. The formation probably extends at least partly across the river and for some distance down stream.

MOUTH RED RIVER.

(820 miles from Cairo.)

The bar here may be in a measure due to the bluff formation which occurs at Fort Adams, 8 miles above.

The above shoals have been selected as being the worst on the river, and also because all, except the two last, may be considered permanent obstructions. Of the other shoals enumerated in my report, a large number are undoubtedly due to the same cause as those selected, in fact many belong to the same system of bars, and there seems little reason to doubt that all the shoals may be traced primarily to the influence of the gravel and heavy sands of this old formation. I say primarily, because there is no doubt in my mind that these bars catch and retain the heavier materials moved by the river. They have already greatly increased in size, and this gain is still going on probably with an increasing ratio, as the amount of sediment poured into the river must, for the reasons set forth at length in my report, increase from year to year as the country along the main river and its tributaries is settled and brought under cultivation. The evidence for this augmentation in the amount of sediment poured into the river is furnished by the enormous increase in the width of the stream which has taken place within the last 50 years, and which is clearly shown by comparing the widths as given by the maps of the reconnaissance made in 1821 with those determined by the examination made under my direction in 1874. This increase in width must depend upon two things: first that the banks are more easily eroded than the bed can be scoured, and, second, that the actual volume of material, solid and fluid, passing through any given section has been increased. Now, there is, I believe, no reason for supposing that the volume of water discharged has been increased, so that the increase must lie in the volume of the sediment moved by the water, and this there seems abundant reason for believing is the true explanation. Were it not for the facility with which the cross-section of the stream can be maintained by lateral extension, the increase in the amount of the deposits on the bed would before this have shown itself in a raising of the flood-line, of which there is no evidence, or, at least, there would have been a general filling up of the deep pools between the bars, but this also is believed to be contrary to the facts.

I had often heard it asserted by old pilots that the river had greatly increased in width within their recollection, but never had an opportunity of verifying the fact till I saw the maps of the reconnaissance made by Captain Poussin and some other officers of the Corps of Engineers and Topographical Engineers in 1821. I have had careful measurements made from this map of the high-water widths between banks, and in the accompanying table these widths are compared with the corresponding ones taken from the maps of 1874.

It must be stated, however, that the difference between these measurements does not give the actual erosion, but only the difference between the erosion of one bank and the growth of the other.

I find that at points where no great change was to be expected, viz, at places where the river flows against bluffs or banks that erode slowly, the widths are about the same, whereas in the long shoal reaches and in the apices of bends, most of the enlargement has taken place. This agrees well with observed facts, so that I think these measurements may be taken as at least relatively correct, especially where averages are used. The mean of 319 measurements shows that for the whole length of the river the average increase in width since 1821 amounts to 74.3

per cent. In order to show these widths more conveniently, I have caused a diagram to be prepared, of which a copy is inclosed herewith. The widths in 1821 and 1874 are here shown plotted as ordinates on a base line which gives to scale the measured distance from Cairo of each point where measurements were taken. On the same sheet the comparative widths between Cairo and Saint Louis are shown, the recent widths for this section being taken from the maps of the United States survey made under the direction of Colonel Simpson, Corps of Engineers. A third diagram on the same sheet gives the comparative widths between Cairo and New Orleans, averaged for lengths of 50 miles, and also the percentage of increase in width. To this latter diagram I would invite special attention.

It will be seen that in 1821 the width of the river decreased rapidly from the mouth of the Ohio to the vicinity of Memphis, interrupted only by two swells in the neighborhood of New Madrid and Plum Point or the First Chickasaw Bluffs, where we have reason, as stated before, to think the river crosses ridges of hard material. Below Memphis the decrease in width was more gradual, but continued along the whole Yazoo Bottom, reaching the minimum width between Vicksburg and Grand Gulf. At the mouths of the Saint Francis and Arkansas and White Rivers the width increases, and a slight widening is also noticeable in the neighborhood of Lake Providence. At the first points mentioned it is almost certain that the river crosses ridges of the old formation, and at the latter point it is highly probable that the same thing occurs.

From Vicksburg to Baton Rouge the river is never far from the bluffs; it undoubtedly frequently comes in contact with the bluff formation and is influenced thereby. The diagram shows a rapid increase of width from Grand Gulf to the vicinity of Ellis's Cliffs. Then there was a slight decrease in the neighborhood of Red River, followed by an increase which attained a maximum near Baton Rouge. Thence to New Orleans there was an approximately uniform width.

The diagram shows that in 1874 the width from Cairo to New Madrid was pretty uniform, but from this point it rapidly increased, reaching a maximum in the vicinity of Plum Point at the head of the Chickasaw Bluffs. Thence to Memphis it decreased rapidly, but after passing Memphis it again increased, attaining a maximum near the mouth of Arkansas River. Then the width decreased in the neighborhood of Greenville, followed by another great increase, which culminated near Vicksburg. From this point to Natchez the width diminished. Then came another increase, culminating, as in 1821, between Ellis's Cliffs and Fort Adams; then a decrease in the vicinity of Red River, followed by an increase culminating near Baton Rouge. Thence to Donaldsonville the width diminished rapidly, and this decrease continued at a more gradual rate to New Orleans.

This line of 1874, with the lower line of the diagram, which gives the percentage of increase of width since 1821, shows that there has been a marked increase in the already great width between New Madrid and Memphis, but that the scene of greatest activity has been the whole front of the Yazoo Bottom, and beyond this as far down as Natchez. As additional corroboration of the accuracy of this astounding discovery, the history of recent cut-offs may be cited. From the year of Poussin's survey to the present time, 14 cut-offs have occurred, of which the following is a list:

Needhams.
Devil's Elbow, above Island No. 37.
Commerce.

Grand Cut-off.
Bordeaux.
Horse Shoe.
Napoleon.
American.
Bunch's.
Terrapin Neck.
Vicksburg.
Palmyra.
Shreves.
Raccourci.

Two on this list, Grand and Bordeaux, were changes from a very long bend into an island chute, but were in every way equivalent to cut-offs, and due to the same causes.

Of the above list, the two first are above Memphis, and one of these, Needham's, occurred before Poussin's survey was made, while the two last, which were artificially produced, are near the mouth of Red River.

The remaining ten are located in the section of river which we are now considering, and show plainly enough that very great erosion has been in progress there.

The lower portion of the stream, from Natchez to Baton Rouge, shows also a marked increase of width, and this section covers a part of the river which is comparatively shoal, though not yet sufficiently so to attract much notice.

The enormous increase in width between Memphis and Natchez more than corroborates the statement made in my report of 1875, on the authority of old pilots, that the area of difficult navigation had progressed down-stream from Plum Point to Lake Providence. The diagram which I have submitted shows that the causes to which this shoaling has been due have been in operation as far down at least as Baton Rouge, and there is no reason for imagining that their effects have ceased. I still hold the opinion expressed in my previous report that these great changes in the character of the river are due to the enormously-increased amounts of sediment brought in by the various tributaries, this increase being mainly due to the altered condition of the banks and adjacent country, brought about by settlement, cultivation, &c. If this theory be correct, the causes enumerated are still at work over an extent of country which increases every day, and further deterioration in the navigability of the main stream and its tributaries must be expected. In further confirmation of the correctness of this view, I will refer again to the diagram. From this it would appear that at the date of the old survey the Chickasaw Bluffs and their outlying spurs and gravel ridges formed a series of dams, behind which the sediment brought in by the northern tributaries was arrested.

At the same time the country along the Yazoo Bottom was probably but little settled, and the banks of the southern tributaries were still less so. Under those circumstances the river had attained a comparatively stable regimen, as is evident from its comparatively small width. Since that date the banks of the Mississippi have been thickly settled and brought under cultivation, and the same is true of the tributary streams. Arkansas River fifty years ago was a narrow and deep stream, with little bank erosion; now it is wide and shallow, and its banks are rapidly eroded, causing a great increase in the amount of sediment brought into the Mississippi. To this must be added the sediment coming from above, due to the northern tributaries, and to the great erosion between Cairo and Memphis, and also the contributions from the eroded banks themselves. If further evidence is required of the great influence exerted upon the regimen of rivers by the amount of sediment which is carried into them, I would refer to the accounts which come to us of the enormous changes which have been brought about within recent years in the character of the Sacramento and other California rivers by the introduction of hydraulic mining.

Before leaving this subject I wish to call attention to the marked contraction in the general width shown by the diagram to occur in the vicinity of Memphis and Greenville. Near the latter place there are several bends whose banks are mainly composed of clay, which erodes slowly, and it is probable that some similar explanation will account for the stability of the banks in the vicinity of Memphis.

In submitting this report, which contains the explanation and corroboration of some of the more important facts noted in my report of 1875, I desire to reiterate the main conclusions at which I had then arrived, viz:

1. That there are natural causes at work which, unless checked or counteracted, will eventually destroy the navigability and usefulness of our Western rivers.
2. That there are so many and such great difficulties to be encountered in the improvement of the Lower Mississippi, that only a moderate amelioration, suited to the present wants of navigation, should at present be contemplated.
3. That the improvement of the river to its full capacity can only follow, not precede, the improvement and regulation of the tributaries.

I am, general, very respectfully, your obedient servant,

CHAS. R. SUTER,
Major of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

Comparative widths of the Mississippi River, 1821 *and* 1874.

Location.	Miles below Cairo.	Widths.	
		1821.	1874.
Bird's Point	2	3,400	4,200
Mayfield	5	3,900	2,800
Three miles below	8	3,000	3,400
Head of Island No. 2	10½	3,600	3,400
Across Islands Nos. 3 and 4	14	6,800	10,800
Three miles above Columbus	17	2,800	2,200
Columbus	20	2,200	1,900
Chalk Bluff	23	2,900	3,400
Foot of Island No. 5	27	3,600	4,750
Bayou du Chien (Hickman)	34	3,700	3,700
Two miles below Hickman	37	2,100	3,600
French's Point	40½	2,300	3,400
Saint James	43	2,600	3,700
Island No. 8	44	7,400	13,800
Foot of Island No. 8	48	3,000	2,400
Phillips's Landing	51	4,200	6,000
Donaldson's Point	56	3,200	4,500
Bend of Island No. 10	59	5,400	6,800
Below Island No. 10	62	3,000	3,800
Lingee's	65	2,900	3,800
New Madrid	68½	4,100	4,800
Head of Island No. 11	70	3,600	4,500
Middle Island No. 11	74	2,800	4,100
Point Pleasant	77½	4,600	4,400
Tiptonville	83	4,000	4,400
Riley's	86	4,100	3,800
Atkinson's	89½	7,500	7,800

Comparative widths of the Mississippi River, 1821 *and* 1874—Continued.

Location.	Miles below Cairo.	Widths.	
		1821.	1874.
Foot of Island No. 13	92½	3,400	3,800
Phillips	94	3,000	3,700
Hathaway	102	3,100	4,000
Gayoso	104	3,000	4,200
Caruthersville	108	2,600	5,300
Booth's Point	115	2,200	2,600
Cottonwood Point	120	2,600	4,200
Midway	123½	1,600	2,800
Island No. 21	127	5,500	10,800
Dyersburg	131½	3,500	3,000
Hale's Point	132½	3,200	5,000
Rucker's Point	137	3,600	3,600
Island No. 25	140	3,600	4,600
Island No. 26	145½	1,800	4,200
Daniel's Point	150	1,400	3,200
Ashport	152	3,800	9,500
Fletcher's Field	157	4,500	9,200
Plum Point	163	3,600	7,300
Foot Bullerton Tow-head	168	3,100	8,000
Head Flower Island	169	3,000	7,400
Narrows below Fort Pillow	174	2,300	2,100
Island No. 34 (both channels)	178	5,600	6,000
Morgan's Point	181	2,400	3,400
Foot Hatchee Island	183	2,600	3,000
Chickasaw Bluff No. 2	185	1,700	1,900
Head of Island No. 35	187	1,600	3,800
Middle Island No. 35	193	2,400	5,600
Pecan Point (foot No. 35)	198	2,500	4,000
Apex of bend (Dean's Island)	204	5,000	7,600
Foot of Island No. 37 (Cottonwood Point)	212	2,200	2,500
Apex Devil's Elbow	216	3,200	3,400
Head Fogleman's Chute	218	2,400	3,400
Brandywine Bend	223	2,600	4,000
Bateman's	226	3,400	4,200
Foot of Island No. 39	228	1,600	4,200
Eldorado	231	1,900	3,000
Beef Island Bend (Island No. 40)	234	3,600	4,200
Rodman's Point (foot No. 40)	239½	2,400	3,200
Head of Hen and Chickens	244	1,500	2,600
Wolf River (Memphis)	248	1,800	2,600
Fort Pickering	250	1,600	1,600
Reeve's Bar	258½	1,300	3,000
Horn Lake Landing	262	2,000	4,600
Head of Island No. 48	264	1,900	2,000
Head of Island No. 50	271	1,700	2,600
Middle Island No. 50	274	1,500	2,200
Foot of Buck Island	280	1,800	3,900
Blue's Point	285	2,900	6,000
Above Dr. Peters's	288	2,100	2,600
Ashley Point	292	2,400	5,000
Head of Bordeaux Chute	297	2,000	2,400
Foot of Bordeaux Chute	301	1,900	3,200
Hardin's Point	305½	3,300	5,200
Head of Saint Francis Island	311	1,700	4,500
Shoofly Bar	313½	3,000	7,600
Foot of Saint Francis Island	316	4,500	8,800
Prairie Point	321	2,000	3,100
Bend above Helena	323½	4,800	8,000
Helena	327	1,900	5,200
Grant's Pass	332	2,100	9,500
Delta Landing	337	1,900	3,000
Friar's Point	342	2,600	3,400
Foot Horseshoe Cut-off	344	1,700	2,300
Miller's Point	347	1,800	1,800
Foot of Old Town Bend	351	1,600	2,100
Head of Island No. 62	354	3,400	6,800
Foot of Island No. 63	356	1,500	1,400
Head of Island No. 64	361	1,800	2,300
Foot of Island No. 64	365	1,900	4,100
Sanford's Landing	370	2,100	3,600
Head of Island No. 66	373	1,800	3,200
Bend of Island No. 66	375	2,000	5,500
Hush Puckney Creek	377	1,400	3,300
Foot of Island No. 66	380	1,800	3,100
	383	1,900	3,400
	385	2,000	8,300
	386	2,0[illegible]	[illegible],900
Middle Island No. 67			

ributions from the

Comparative widths of the Mississippi River, 1821 *and* 1874—Continued.

Location.	Miles below Cairo.	Widths.	
		1821.	1874.
Foot of Island No. 67	390	1, 700	2, 600
Head of Island No. 69	392	1, 800	3, 400
Bend of Island No. 69	395½	2, 300	3, 400
Foot of Island No. 69	397	1, 500	2, 400
Head of Island No. 70	400	1, 700	4, 300
Middle Island No. 70	404	4, 500	8, 300
Foot of Island No. 70	407	2, 400	8, 800
	409	1, 800	3, 500
Scrubgrass Bend	411	1, 800	8, 300
Concordia Bayou	415	1, 700	2, 700
Victoria Bend	418	1, 900	5, 200
Mouth of White River	420	1, 800	2, 600
	422	2, 000	4, 200
Rosedale Bend	425	3, 000	4, 400
Mouth of Arkansas River	428	1, 800	3, 300
Ozark Island	431	5, 300	....
	434	2, 400	6, 000
	436	1, 800	3, 700
Mohawk Landing	441	2, 000	3, 500
	443½	3, 500	10, 000
Middle Island No. 76	445	5, 000	10, 900
Foot of Island No. 76	447	3, 000	6, 100
Jersey Point	449	2, 100	4, 800
Catfish Tow-head	451½	2, 500	7, 100
Head of Cypress Bend	454	1, 600	4, 200
Cypress Bend (apex)	455	2, 700	8, 600
Cypress Bend	459	1, 700	4, 700
Foot of Cypress Bend	463	2, 000	3, 700
Choctaw Bend	466	1, 900	9, 500
Glencoe	467	1, 700	....
Arkansas City	469	1, 800	3, 700
Yellow Bend	471	1, 900	2, 600
Head of Island No. 80	475	2, 000	4, 000
Georgetown Bend	478	2, 100	5, 000
Foot of Georgetown Bend	481	2, 000	3, 600
Rowdy Bend	484	1, 600	4, 700
Head of Island No. 82	488	1, 700	3, 500
Miller's Bend	489½	1, 800	4, 600
Miller's Bend	493	1, 800	3, 100
Foot of Island No. 82	497	1, 600	3, 100
Spanish Moss Bend (Luna)	500	1, 800	3, 900
Solona	504	2, 000	2, 600
Point Chicot	506	2, 300	2, 600
Island No. 83	508	4, 000	3, 800
Greenville	509	2, 400	3, 900
Leland	512	1, 850	3, 800
Head of Island No. 84	516	2, 100	3, 700
Walker's Bend	518	2, 300	5, 800
Foot of Island No. 84	520	1, 700	3, 100
	522½	1, 700	3, 700
Walnut Point	525	....	2, 900
Egg's Point	528	1, 900	2, 700
	529½	2, 100	3, 900
Harwood's Point	531	3, 000	3, 000
Islands Nos. 86 and 87	534	3, 800	5, 700
Rosebank	538	1, 700	4, 500
Foot of Matthews Bend	541	1, 800	2, 700
Head of Island No. 89	545	1, 800	3, 300
Carolina Landing	547½	2, 000	5, 300
Arkansas State Line	550½	1, 700	3, 500
Louisiana Bend	552	1, 700	4, 600
Bunch's Cut-off	556	....	3, 200
Island No. 92	558	1, 700	5, 900
Skipwith	559	1, 700	4, 500
Wilson's Point	560½	2, 700	3, 500
Myersville (Island No. 93)	563	4, 000	7, 400
Homochitta	565	2, 000	4, 200
	567	1, 800	4, 000
Head of Island No. 94	569	1, 900	7, 100
Lake Providence	572	2, 000	3, 800
Lake Providence Bend	575	1, 900	8, 400
Head of Tallula Bend	579	1, 700	2, 000
Island No. 95	582½	1, 800	3, 700
Foot of Tallula Bend	586	1 800	2, 400
	589	1, 800	7, 400
Head Tompkins Bend	593	1, 900	3, 500
[illegible]	599	1, 700	3, 400
Riley's	600½	1, 700	8, 400
Atkinson's	604	....	3, 300

Comparative widths of the Mississippi River, 1821 *and* 1874—Continued.

Location.	Miles below Cairo.	Widths.	
		1821.	1874.
Head of Milliken's Bend	609	1, 600	3, 400
	614	1, 600	4, 200
Foot of Milliken's Bend	616	1, 600	3, 800
	619	2, 600	7, 100
Pawpaw Island Bend	621	2, 500	4, 800
Foot of Pawpaw Island Bend	625	2, 200	3, 400
Yazoo River	628	1, 600	5, 200
Head of Tuscumbia Bend	631	2, 000	3, 400
Foot of Tuscumbia Bend	634	1, 600	5, 000
Vicksburg Bend	636	1, 500	4, 100
Vicksburg	639	1, 400	3, 400
	643	1, 600	5, 300
	645	1, 600	8, 400
Warrenton	648½	1, 700	3, 000
	650	1, 700	4, 800
	652	1, 700	3, 300
Head of Diamond Island	654	1, 600	5, 800
Middle Diamond Island	656	1, 600	8, 700
Foot of Diamond Island	658½	1, 600	3, 000
New Town Bend	660	1, 600	1, 600
Foot of New Town Bend	664	1, 900	6, 000
Thrasher's Point	674	1, 600	3, 700
Head of Hard Times Bend	675	1, 600	6, 300
Mouth of Big Black River	681	1, 600	3, 600
Below Grand Gulf	683	2, 400	6, 300
White Hall Point	686	1, 600	2, 900
Hardscrabble Landing	689	1, 700	3, 700
Bruinsburg	693	1, 900	5, 000
Below Bruinsburg	695	1, 700	3, 200
Below Saint Joseph	698	2, 300	3, 150
Rodney Landing	702	1, 400	2, 700
Foot of Island No. 111	705½	1, 600	4, 900
	707	1, 600	7, 900
	709	1, 500	3, 800
	710	1, 500	4, 600
Buena Vista	711	1, 400	3, 400
Waterproof	714	1, 600	2, 600
Cole's Creek Island (No. 113)	716	2, 600	2, 100
Foot of Cole's Creek Island	718	1, 900	2, 300
	721	1, 900	5, 100
Cole's Creek Bend	723	2, 400	3, 200
L'Argent	730	1, 900	4, 700
Below Fairchild's Island	736	1, 700	3, 800
Head of Rifle Bend	738	1, 900	3, 600
Rifle Bend	740	2, 000	4, 900
	742	1, 600	2, 100
Cowpen Point	744	1, 500	4, 600
Cowpen Bend	746	1, 600	5, 900
	750	1, 700	2, 600
Natchez	753	2, 000	1, 500
Creek below Natchez	755	1, 900	2, 500
	756	4, 600	4, 200
Natchez Island	757	5, 400	4, 700
	758	2, 500	5, 000
	760	1, 800	2, 300
Saint Catharine's Bend	763	2, 500	8, 200
Saint Catharine's Creek	767	1, 700	2, 600
Ellis's Cliffs	769½	2, 000	2, 900
Pecan Grove	772	2, 300	5, 900
	774	2, 500	4, 800
Head of Glasscock's Island	775	3, 600	5, 500
Do	775½	3, 900	6, 500
Middle of Glasscock's Island	777	4, 000	9, 700
Foot of Glasscock's Island	779	3, 000	2, 600
Head of Dead Men's Bend	782	2, 000	2, 000
Dead Men's Bend	784	2, 000	5, 200
	785½	2, 000	3, 100
Jackson's Point	790	2, 400	2, 400
Union Point	795	2, 200	2, 700
	797	2, 600	5, 100
Palmetto Point	800½	2, 600	2, 700
	801½	2, 400	4, 500
Homochitta River	803	2, 400	2, 300
Consort Point	805	2, 900	2, 700
Buffalo Creek	808	1, 900	2, 600
Fort Adams	809	1, 500	1, 700
Fort Adams Reach	812	1, 900	4, 000
Do	815	2, 200	4, 500
	817½	2, 300	2, 400

Comparative widths of the Mississippi River, 1821 *and* 1874—Continued.

Location.	Miles below Cairo.	Widths.	
		1821.	1874.
Mouth of Red River	818	2, 400	3, 700
Racourci Cut-off	820	....	3, 000
Do	824	....	2, 400
Bayou Tunica	827	2, 000	3, 200
Tunica Bend	830	2, 100	3, 000
	832	2, 500	4, 500
Tunica Island	834	3, 000	8, 600
Foot of Tunica Island	835	2, 900	5, 000
	836	2, 600	2, 500
Head of Morgan's Bend	841	2, 200	2, 350
Foot of Morgan's Bend	846	2, 200	2, 600
Bayou Sara	853	2, 500	4, 200
False River Cut-off	859	2, 400	2, 450
	860	2, 500	2, 550
	861	3, 200	3, 600
Port Hudson	863½	2, 800	2, 000
	866	2, 300	2, 100
Head of Prophet's Island	867½	2, 900	8, 200
Middle of Prophet's Island	870	5, 000	14, 600
Springfield	873	2, 000	3, 200
Head of Baton Rouge Bend	882	2, 200	2, 500
Baton Rouge	887	2, 100	2, 600
	890	2, 100	2, 600
	893	2, 200	2, 600
Duncan's Point	895	2, 600	5, 500
	897	2, 700	2, 500
Manchac Point	900	2, 900	3, 200
	903	2, 000	2, 600
Plaquemine	907	2, 550	2, 900
Luda Bar	913	3, 400	3, 400
Saint Gabriel Church	917	2, 500	3, 000
	920	3, 000	3, 000
Bayou Goula	921	3, 000	4, 400
Point Clair	923	2, 400	1, 900
Head of Claiborne Island	929	2, 400	4, 000
Middle of Claiborne Island	930	2, 500	....
Foot of Claiborne Island	931	2, 600	2, 900
	932	2, 700	4, 500
	934½	2, 400	2, 500
Eighty-one-mile Point	939	2, 700	2, 500
Bayou La Fourche	942	2, 700	3, 300
Above Point Houmas	945	2, 300	2, 900
Above White Hall	950	2, 600	2, 200
Cantrelle Church	959	2, 100	2, 300
	964	2, 800	3, 150
	969	2, 200	3, 400
Bell's Point	975	2, 300	2, 300
	976	2, 300	3, 300
Bonnet Carré	980	2, 400	2, 400
Crevasse of 1874	985	3, 600	4, 600
Bend	992	3, 000	4, 500
Red Church	995	2, 900	2, 700
Above Eighteen-mile Point	1, 000	2, 500	2, 200
Kennerville	1, 003	2, 350	2, 200
Jefferson	1, 007	2, 500	2, 400
Below Carrollton	1, 013	2, 000	2, 100
New Orleans (Canal street)	1, 020	2, 900	1, 900
Below Algiers	1, 023	2, 600	2, 200

Comparative widths in 1821 *and* 1874, *averaged for lengths of fifty miles.*

Miles below Cairo.	Mean widths.		Difference.	Per cent. of increase.
	1821.	1874.		
51	3, 594	4, 591	997	27. 5
102	3, 907	4, 585	678	17. 3
152	2, 954	4, 846	1, 892	64. 0
204	3, 100	5, 331	2, 231	72. 0
258½	2, 269	3, 223	954	42. 0
305½	2, 136	3, 609	1, 473	69. 0
356	2, 464	4, 821	2, 357	95. 6
407	2, 026	5, 116	3, 090	152. 5
459	2, 321	5, 463	3, 142	135. 4
509	2, 041	3, 994	1, 953	95. 7
559	2, 032	4, 100	2, 068	101. 8
609	2, 020	4, 840	2, 820	139. 6
658½	1, 761	4, 816	3, 055	173. 5
709	1, 733	4, 316	2, 583	149. 0
760	2, 162	3, 605	1, 443	66. 7
809	2, 495	4, 081	1, 586	63. 6
859	2, 371	3, 786	1, 415	59. 7
907	2, 628	3, 953	1, 325	50. 4
959	2, 629	3, 057	428	16. 2
1,023	2, 596	2, 811	215	8. 3
Grand means of 319 measurements	2, 439	4, 252	1, 813	74. 3

APPENDIX W 2.

ALLUVIAL BASIN OF THE MISSISSIPPI RIVER.

OFFICE OF THE CHIEF OF ENGINEERS,
Washington, D. C., February 21, 1878.

SIR: Maj. G. K. Warren, Corps of Engineers, president of the Board of Commissioners appointed to investigate and report a permanent plan for the reclamation of the alluvial basin of the Mississippi River subject to inundation, has transmitted to this office a report by Prof. Eugene W. Hilgard and Dr. F. V. Hopkins upon the specimens obtained from borings made in 1874, by direction of the Commission, between the Mississippi River and Lake Borgne.

The report was intended to accompany my annual report for 1877, but the illustrations were not ready in time.

The report is a valuable contribution to our knowledge of the formation of the delta of the Mississippi, and the description and classification of the specimens obtained have a scientific value making it desirable that it should be printed without delay.

I would therefore recommend that it be printed at the Government Printing Office, and that 1,500 copies be obtained on the usual department requisition.

Very respectfully, your obedient servant,

A. A. HUMPHREYS,
Brigadier-General and Chief of Engineers.

Hon. GEO. W. MCCRARY,
Secretary of War.

Approved.
By order of the Secretary of War.

H. T. CROSBY,
Chief Clerk.

WAR DEPARTMENT,
February 26, 1878.

LETTER OF MAJOR G. K. WARREN, CORPS OF ENGINEERS.

ENGINEER OFFICE, UNITED STATES ARMY,
Newport, R. I., November 28, 1876.

GENERAL: I have the honor to transmit herewith a report made by Prof. Eugene W. Hilgard in accordance with a resolution adopted by the Commission of Engineers appointed "to investigate and report a permanent plan for reclamation of the alluvial basin of the Mississippi subject to inundation," of which Commission I was president. This resolution was passed on the 15th of January, 1875, the second day before adjourning *sine die*, as will be seen by referring to the printed record of the proceedings accompanying the report of the commission, H. Ex. Doc. No. 127, Forty-third Congress, second session, and republished in the annual report of the Chief of Engineers for 1875. It is as follows:

> *Resolved*, That the president of the Commission be authorized to transmit the specimens obtained from the borings made under the direction of the commission, at the site of the proposed outlet to Lake Borgne, to Prof. E. W. Hilgard, at Ann Arbor, Mich., for investigation and report; and that an amount not exceeding $400 be set apart from the appropriation for the expenses of the commission to pay for the work.
>
> *Resolved also*, That Professor Hilgard's report, when completed, be sent to the Chief of Engineers, United States Army, and the final disposition of the specimens be left with that officer.

This report is a valuable contribution to our knowledge of the formation of the delta of the Mississippi, besides the aid it affords us in considering the question of making an outlet for the Mississippi floods between the river and Lake Borgne. Its practical importance in the further consideration of the question of a ship-canal is very considerable, by increasing our reliable information as to the character of the material the canal must be excavated in, and its capability to sustain the weight of suitable locks. Dr. Hopkins says that the specimens show no obstacle to the successful prosecution of excavating a canal prism at this locality; and as the formation near Fort Saint Philip, where the canal would be most desirable, is similar to that where the borings were made, we have reason to expect similar favorable conditions there.

The special report of the survey which furnished these borings will be found in Appendix B to the report of the Commission of Engineers already referred to in this communication.

These reports of Professor Hilgard and Dr. Hopkins have a scientific value which alone justifies their being published in good style.

The specimens were divided into two parcels by Professor Hilgard, one part of which he took with him to California, where he was compelled to go for the benefit of his health, and where he has also specimens of borings made at other places in the Mississippi delta reserved for future comparisons. I would respectfully suggest leaving what he has with him, and sending the others to New Orleans to be deposited there for future reference. The resolutio n of the commission placed them, however, at your disposal, which, if different from what I suggest, will doubtless be for the better.

Very respectfully,

G. K. WARREN,
Major of Engineers and Bvt. Maj. Gen., U. S. A.

Bvt. Maj. Gen. A. A. HUMPHREYS,
Brigadier-General and Chief of Engineers, U. S. A.

REPORT OF PROFESSOR EUGENE W. HILGARD.

UNIVERSITY OF CALIFORNIA,
Berkeley, November 10, 1876.

DEAR SIR: I submit herewith my report of the examination of the specimens collected from the borings made in 1874, between the Mississippi River and Lake Borgne, under the superintendence of Prof. C. G. Forshey, by order of the United States Delta Commission.

These specimens, referred to me by your order, reached me at Ann Arbor, Mich., in February, 1875. As I was then preparing to change my residence to this place, it was thought best not to risk the whole set of specimens on so long a journey. I therefore took samples, amounting to about one-third of the originals, in such a manner as to insure a fair average of each. In a few cases, where it seemed necessary to examine a larger bulk, the larger portion was taken, and the smaller specimen, together with the remaining originals, returned to your custody.

A few of the original (10 ounce) bottles were broken when the set reached me, but in no case was the specimen altogether lost. The set of samples taken by me reached here uninjured.

Unfortunately (as stated to you at the time) the condition of my eyes was such as to preclude microscopic work; but I had reason to anticipate a speedy recovery from the disorder by a change of climate. In this hope I have been disappointed. I found that the identification of the non-microscopic organizations would be quite as much as my eyes could resist, and was fortunate in obtaining the assistance of my former co-worker, Dr. F. V. Hopkins, late of the University of Louisiana, and for several years in charge of the geological survey of that State. Already familiar with the general problem as well as with the materials to be examined, and an expert microscopist and draughtsman, Dr. Hopkins has, I feel assured, accomplished at least all that it would have been in my power to do in the matter of specific determinations, and more in furnishing drawings of the objects, which may serve for future identification. With the conscientiousness of a true scientist, he has furnished the facts themselves, instead of straining them to adapt them to received names, which are but too often as yet based upon partial and hasty observation, and a desire to add another name, however meaningless, to the confused heap of microscopic nomenclature.

The classification of the upper strata is of course based exclusively upon the microscopic characters; while among the marine stages, the larger fossils have in a measure served for distinction, or rather perhaps for identification, in cases where mere differences of material carried with them a correspondingly greater difference of the microscopic than of the larger fossils. Thus the finer sand of the off-shore portions of stratum 4 would, on the basis of microscopic organisms alone, have been classed as a different stratum, had not the absolute identity of the larger fossils forbidden a separation.

The following appendixes accompany my report as a part thereof:

Appendix No. 1. Abstract of record of borings.

Appendix No. 2. Report of Dr. F. V. Hopkins on the microscopic examination of the specimens.

Appendix No. 3. Detailed record of the examination of specimens.

Appendix No. 4. List of microscopic organism, with two plates. By Dr. F. V. Hopkins.

Appendix No. 5. Synoptical table of the larger organisms, and notes on fossils, with one plate. By E. W. Hilgard.

All of which is respectfully submitted.

Very respectfully, your obedient servant,

EUG. W. HILGARD.

Bvt. Maj. Gen. G. K. WARREN,
President of Commission of Engineers, &c.

REPORT.

The ground on which the borings were made (see map) is the neck of land lying between the Mississippi River and Lake Borgne, about 7 miles below the city of New Orleans, and fronting on a portion of what is known as the "English Turn" of the river. The area embracing the borings is of a trapezoidal shape, with a frontage of 6,000 feet on the river and 14,500 on the lake shore, which here trends about N. 12° W., while the course of the river is nearly S. E. Nearly from the points of nearest approach of river and lake (28,200 feet) a line of four borings (Nos. 1, 8, 9, and 14) runs across, bearing about E. 2° N., and forming the southerly limit of exploration; while the northward one is formed by a line about 34,000 feet long, bearing due northeast. Within

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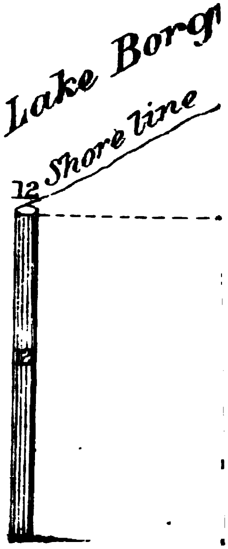

formation, as is abundantly manifest from the outcrops at Port Hudson, on Wolf River, Mississippi, and at the five islands on Vermilion Bay.* But whether stratum 8 of the Lake Borgne borings shall be accounted as belonging to the same age, or merely as an older portion of the modern cypress-swamp stratum, is a question for the final determination of which the data are thus far inadequate.

THE "BLUE DELTA CLAY."

Dr. Hopkins's investigation of the microscopic character of the strata of dark-colored, brown or blue clays occurring in the borings, throws some welcome light on the vexed question of the "blue delta clay" which is found almost everywhere in the delta and coast region of Louisiana and Mississippi.

In regard to this I have heretofore maintained, on the basis of stratigraphical and partly of palæontological characters, that these clays may be referred substantially to two different epochs, viz, the lower and more continuous and compact strata, to the time at which a slow depression of the southern coasts, at least, converted the Lower Mississippi Valley into a swamp or marsh through which the continental waters found their way without any definite main channel representing the Mississippi River of to-day; while there is another class, the same as now in progress of formation, which represent either the cypress-swamp and marsh deposits, or the very peculiar feature of the mud-lumps, which cause the great river to push out its "passes" into the Gulf in a manner wholly without parallel in any other delta of the world. It has heretofore been surmised that even the city of New Orleans might not be above the landward limit of the mud-lump formation. As regards the distinction of the older from the more recent clays, I have held that in most cases it must be determined by stratigraphical and hypsometrical data, since it was not reasonably supposable that there should be much difference in the palæontological or lithological features.

On the question of the mud-lump nature of the clay underlying New Orleans, the microscopic investigation of stratum 11 is quite conclusive. There is no analogy whatsoever between the mud-lump clays examined by me (Am. Jour. Sci., June, 1871, p. 366), all of which contained a large proportion of marine organisms, and the purely fresh-water material examined by Dr. Hopkins. The city undoubtedly stands on a cypress-swamp clay, at least to a depth of about twenty feet.

It is not usually very difficult for a practiced eye to distinguish a sea-marsh clay from the cypress-swamp deposit; and resort to the microscope will always promptly settle the question. But Dr. Hopkins has shown the interesting fact that there is such a marked difference between the microscopic organisms of the ancient and modern sea-marsh (No. 8 and No. 12), that even these can probably be hereafter distinguished with considerable certainty by the aid of the microscope. The following table shows the chiefly important microscopic fossils of the two deposits:

STRATUM NO. 8.

Orbulina universa.
Rotalia 2 sp.
Grammostomum Americanum.
Grammostomum sp.
Lenticulum discus.
Rosalina Beccarii.
Campylodiscus sp.
Melosira distans.
Melosira, 3 sp.
Navicula Gundleri.
Navicula 2 sp.
Cocconeis sp.
Pinnularia viridis.
Pleurosigma 2 sp.
Eunotia gibberula.
Fragillaria capucina.
Fragillaria, 2 sp.
Cocconema lanceolatum.
Triceratium sp.
Cyclotella punctata.
Coscinodiscus radiatus.
Synedra acuta.
Closterium sp.
Leptocistinema Kinahani.
Spongolithis acicularis.
Sp. mesogongyla.
Spongolithis sp.
Lithostylidium denticulatum.
Lithostylidium quadratum.

STRATUM NO. 12.

Orbulina universa.
Rotalia pachypleura.
Rotalia sp.
Planulina elegans.
Globigerina sp.
Campylodiscus sp.
Melosira distans.
Navicula viridis.
Navicula fulva.
Fragillaria sp.
Cocconema lanceolatum.
Rhizosolenia sp.
Nitzschia sp.
Cyclotella sp.
Synedra acuta.
Synedra sp.
Spongolithis aspera.
Spongolithis inflexa.
Spongolithis acicularis.
Lithostylidium denticulatum.
Lithostylidium crispum.
Lithostylidium quadratum.

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* Smithsonian Contr. Knowl., No. 248, pp. 5, 9, 27.

A comparison of the detailed record of Dr. Hopkins' observations (Appendix III) will show that the difference shown in this table, together with some lithological ones, runs very fairly through the whole of the specimens examined.

It would, of course, require observations from other points to determine that this difference is a consistent one over large areas, and can be relied upon. Stratum 8 may be a true delta deposit of the present Mississippi, such as it has been since the re-elevation of the continent which determined the erosion of the present trough of the river. The fact that an apparently fluviatile stratum (No. 2) occurs lower down, may be taken as an indication that both Nos. 2 and 4 fall within the modern period of delta formation. Yet it is not to be supposed that during the period of depression some definite channels, such as that indicated by strata Nos. 2 and 7, did not exist here as well as in the region above, at Port Hudson (Smithsonian Contr. No. 248, p. 5), and elsewhere. But in a "drowned" delta in course of depression, such channels would, on the whole, be smaller, shallower, and more shifting than during the period of elevation, or the quiescent one that now prevails.

On the other hand, stratum No. 8 might be regarded as the denuded remnant of a much thicker stratum deposited during the period of depression, and therefore sensibly contemporaneous with the "Port Hudson clay." If, as seems probable, it extends to seaward beneath the waters of Lake Borgne, it is difficult to conceive it otherwise than as the continuation of the "blue-clay bottom" of Mississippi Sound, about whose antiquity, and connection with the Port Hudson beds proper, there can scarcely be a question. But until actual examination shall have determined these points, and especially the microscopic similarity of the "blue-clay bottom" to stratum 8, speculation as to how the latter came to occupy its present position can hardly lead to any useful conclusions.

It was not, of course, to be expected that borings reaching only to a depth not greater than that sometimes attained by the Mississippi River itself, should throw any direct light on the question of the depth of the delta deposits in the upper delta plain. Yet, in so far as the results of the present investigation corroborate the steady and rapid increase of the marine character as we descend, as well as an appreciable difference of the fauna from that now ordinarily thrown ashore on the delta beaches, they tend to corroborate also my previous conclusion that the delta deposits proper, at least at and above New Orleans, have a comparatively inconsiderable thickness; and that this anomalous structure of the delta of the great river is in direct causal connection with the equally anomalous phenomenon of the mud-lumps.

APPENDIX I.

ABSTRACT OF RECORD OF BORINGS.

BORING No. 1.

(*On river front.*)

	0.	Black soil.
11.	5.	Stiff brown clay.
8.	10.	Same, more sandy.
	15.	Sandy clay.
	20.	Same.
	25.	Same, with wood chips.
	30.	Do. do.
	35.	Do. do.
	40.	Do.
	45.	Do.
	50.	Do.
	55.	Do., harder.
	60.	Pure blue clay.
	65.	Do.
	70.	Do. to 73 feet.
4.	75.	Quicksand, with fine shells.
	80.	Sand and shells.
	85.	Do.
	90.	Do. to 95 feet.
1.	95.	Blue clay, like first stratum.
	100.	Blue clay, as above.

BORING No. 2.

(*On river front, 2,000 feet from No. ——*)

	0.	Black soil.
11.	5.	Sandy.
	10.	Yellowish-brown clay.
	15.	Do.
	20.	Blue clay, slightly sandy.
	25.	Do.
	30.	Do.
	35.	Do.
8.	40.	Do.
	45.	Do., gas jet burning 2 feet high.
	50.	Do.
	55.	Do.
	60.	Do.
	65.	Do. to 68 feet.
4.	70.	Sand and shells.
	75.	Do.
	80.	Do. to 82 feet.
	85.	

BORING No. 3.

(*Said to be highest point on river front.*)

	0.	Light sandy soil.
11.	5.	Do.
	10.	Do.
	15.	Yellow clayey sand.
	20.	Same, much less sandy.
	25.	Blue clay, no sand, cypress chips.
	30.	Same.
8.	35.	Sand and mud, bluish.
	40.	Same, more clay.
	45.	Soft blue clay, very slightly sandy.
	50.	Same as above.
	55.	Do.
	60.	Do.
	65.	Do.
	70.	Same to 72 feet, strong jet of combustible gas.
4.	75.	Fine quicksand.
	80.	Do.
	85.	Do., with shells.
	90.	Do.
	95.	Do. to 97 feet, thence to
1.	100.	Blue clay.

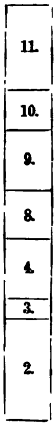
BORING No. 4.

(*River front.*)

	0.	Stiff, black clay soil.
11.	5.	Dark-brown mud.
	10.	Brown mud, very sticky.
	15.	Same.
	20.	Blue clay, with little sand, wood chips.
8.	25.	Same as above.
	30.	Do.
	35.	Blue clay, very sandy, with wood chips.
	40.	Same, some water.
	45.	Do.
	50.	Do.
	55.	Same, less sandy.
	60.	Blue clay to 64 feet.
4.	65.	Quicksand.
	70.	Bluish-gray quicksand.
	75.	Do.
	80.	Do.
	85.	Do.
	90.	Do. to 91 feet.
1.	95.	Blue clay, with shells.
	100.	Do.

BORING No. 5.

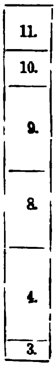
(*In cypress swamp* 7,000 *feet from river, northwest end of second tier.*)



0. Black surface soil.
5. Light-brown mud, soft.
10. Same, with wood chips.
15. Blue mud, sandy, and chips.
20. Do.
25. Do., driving harder.
30. Quicksand, with chips.
35. Do.
40. Do. to 45 feet.
45. Blue clay, some sand.
50. Same to 53 feet.
55. Blue clay, harder, to 57 feet.
60. Quicksand, with shells.
65. Do. do
70. Do. to 72 feet.
75. White soapstone clay to 78 feet.
80. White and red sand.
85. Do.
90. Do.
95. Do., with fine shells, not separable.
100. Continues same.

BORING No. 6.

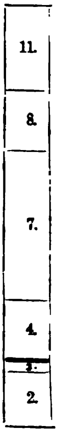
(*In cypress swamp* 2,500 *feet southeast of No.* 5, *in second tier.*)



0. Black surface soil.
5. Soft brown mud and chips.
10. Same, with sand.
15. Same to 20 feet.
20. Gray and black quicksand.
25. Do.
30. Do.
35. Do. to 40 feet.
40. Same material, more clayey.
45. Do. to 50 feet.
50. Blue clay.
55. Same to 59 feet.
60. Quicksand, with shells.
65. Do.
70. Do. to 72 feet.
75. Quicksand, very fine.
80. Same to 81 feet.
85. Blue clay, driving hard.

BORING No. 7.

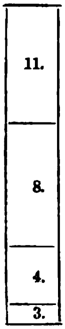
(*In cypress swamp* 3,000 *feet southeast from No.* 6, *in second tier.*)



0. Black swamp mud.
5. Stiff, blue clay.
10. Do., more sandy.
15. Do.
20. Do.
25. Do., sand increasing.
30. Do., with much coarse sand.
35. Coarse sand only.
40. Do., dark-gray tint.
45. Coarse sand as above.
50. Do.
55. Do.
60. Do.
65. Do., hard.
70. Same to 72 feet, then indications of blue clay.
75. Fine sand and shells, with some clay.
80. Do.
85. Same to 87 feet, then blue clay to 88 feet.
90. White sand, with little clay, and shells.
95. Do.
100. Same as above.

BORING No. 8.

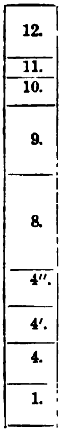
(*In cypress swamp* 2,500 *feet southeast of No.* 7, *southeast end of second tier.*)



0. Stiff black cane soil.
5. Dark clay, little sand.
10. Do. do.
15. Same to 17 feet.
20. Blue clay.
25. Same, more sandy.
30. Do.
35. Do., less sand.
40. Blue clay.
45. Do.
50. Do.
55. Do.
60. Same, sand increasing, to 63 feet.
65. Quicksand, with fine shells.
70. Do. do.
75. Same to 77 feet.
80. Blue clay and shells.

BORING No. 9.

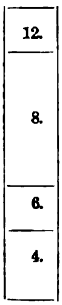
(*In cypress swamp,* 15,000 *feet from river front.*)



0. Soft mud, dark brown.
5. Same to 10 feet.
10. Fine blue clay.
15. Do., with root chips.
20. Same to 24 feet.
25. Coarse gray sand.
30. Do.
35. Do.
40. Sand and clay mixed.
45. Do. do. to 50 feet.
50. Blue clay.
55. Do.
60. Same clay to 64 feet.
65. Sand, chips from log, and shells.
70. Same to 73 feet.
75. Blue clay and shells to 80 feet.
80. Sand and blue clay, shells.
85. Do. do.
90. Same to 91 feet.
95. Blue clay.
100. Same.

BORING No. 10.

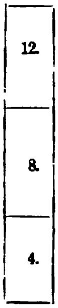
(*In marsh prairie, bank of bayou, one mile from lake shore.*



0. Dark swamp mud.
5. Same, bluish.
10. Same, and blue mud.
15. Blue mud.
20. Do.
25. Do.
30. Do.
35. Do.
40. Do.
45. Do.
50. Do. to 55 feet.
55. Gray sand and shells, with little clay.
60. Do. do.
65. Do. do.
70. Do. do.

BORING No. 11.

(*In marsh prairie*, 1.76 *miles from lake shore.*)



0. Brown mud soil, with cane.
5. Same.
10. Do.
15. Do.
20. Do., and rootlets.
25. Do. to 30 feet.
30. Blue mud.
35. Do. to 40 feet.
40. Blue clay.
45. Do.
50. Do. to 52.
55. Gray sand and shells.
60. Do. do.
65. Do. do.
70. Do. do.

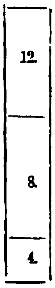
BORING No. 12.

(*On lake shore, in line with Nos.* 5 *and* 11.)

0. Soil, wet and sticky.
5. Brown mud, with matted roots.
10. Do.
15. Do.
20. Do.
25. Do. to 26 feet.
30. Blue clay mud.
35. Same to 40 feet.
40. Blue clay.
45. Do.
50. Do. to 55 feet.
55. Sand and shells, with some clay.
60. Do. do.
65. Do. do.
70. Do. do. to 71 feet.

BORING No. 13.

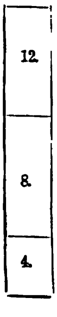
(*Lake shore, mouth of Bayou Chaperon.*)



0. Soft wet mud.
5. Same, dark colored.
10. Do.
15. Do.
20. Do.
25. Do., harder.
30. Same, with blue clay.
35. Do. do.
40. Blue clay.
45. Stiff blue clay.
50. Do.
55. Same to 56.
60. Sand, with little blue clay.
65. Same, with shells, to 69 feet.

BORING No. 14.

(*On lake shore, in line with Nos.* 1, 8, *and* 9.)



0. Surface very wet soft mud.
5. Soft dark mud.
10. Do.
15. Do.
20. Do., getting bluer to 25 feet.
25. Blue mud or clay, with little sand.
30. Same, less sand.
35. Do., no sand.
40. Same, harder.
45. Same, pure light color.
50. Same, harder, gray.
55. Same, to 56 feet.
60. Bluish-gray sand.
65. Same, with shells.
70. Do. do.

APPENDIX II.

REPORT ON SPECIMENS OF BORINGS, BY DR. F. V. HOPKINS.

REFERRING TO APPENDICES III AND IV.

NEW ALMADEN, *October* 7, 1876.

SIR: The undersigned having completed the examination of the series of specimens from the borings made in the survey between the Mississippi River and Lake Borgne, furnished by you, respectfully offers the following report of the results:

The object aimed at was to obtain a geological section of the tract embraced in the survey, it being of course of great practical importance in the construction of an outlet that the character of the beds through which it is to pass should be thoroughly understood.*

But besides the settling of this practical point, the study of these delta deposits of the Mississippi River is of considerable scientific interest. Very little opportunity has as yet been afforded to learn their peculiarities with accuracy. Your own investigation of the artesian well of New Orleans stands as the only contribution yet made to our knowledge of the larger fossils that they contain; and even in it, the microscopic forms were not closely studied. In the present instance the latter are of primary importance, for the small specimens that have been preserved from the borings do not present to the naked eye sufficient differences to justify their division into strata upon superficial observation alone. In making the section, therefore, after separating the calcareous from the non-calcareous beds by chemical means, the proportion of clay in each was approximately determined by washing; the peculiarities of the grains of quartz and other minerals, as well as of the vegetable matter present, were noted with the microscope, and finally all organisms found were carefully figured and tabulated, as a check to the conclusions drawn from other sources.

The washing was conducted upon a fixed plan. A piece of soil as large as a hazelnut was agitated with water four inches deep, in a test tube half an inch in diameter, until its particles were thoroughly separated from each other. The tube was then allowed to stand for five minutes, by which time the sand, organisms, and vegetable matter, with the coarser portion of the clay, had settled to the bottom. The water with the finer portion of the clay was then decanted into another tube, fresh water poured upon the residue to the same depth of four inches, and the agitation repeated. This time the tube was only allowed to rest one minute before decantation, the third time half a minute, and the fourth but fifteen seconds. If at any time the water appeared free from clay at the end of the period allotted to the settling, the deposit was judged to be free from that ingredient also, and the process was not repeated. The number of decantations used is, therefore, a rough measure of the proportion of clay in the soil. The deposits in the different tubes were all examined separately under the microscope; the organisms occurring chiefly in the two last.

Not being a specialist in the subject of Diatoms and Desmids, much study was expended in the effort to determine the species observed, but with very partial success. My acknowledgments are due to Doctor Harkness, a member, and to Prof. William Ashburner, the president, of the San Francisco Microscopical Society, for obtaining for me access to the excellent library of that institution while prosecuting this research. The only works at hand that were of use were Ehrenberg's "*Microgeologie*," Pritchard's "*Manual of the Infusoria*," Godfrey and Henery's "*Micrographic Dictionary*," Adam Schmidt's "*Monograph upon certain genera of Diatoms*," and the articles of Doctor Brightwell in the "*Microscopic Journal*." With so limited a list of authorities at my disposal it is very probable that many species marked "undetermined" are described elsewhere, and that the names that have been taken from Ehrenberg may have been superseded ere now by the more accurate labors of recent authors. Under these circumstances it becomes necessary to give my figures, which are carefully drawn from the objects themselves, in order to show what the strata really contain. It is by no means unlikely that a number of the species are new, as so little attention has as yet been paid to these delta deposits by scientific men.

Where several species belonging to the same genus are not determined, they have been numbered; and where even the genus is unknown, they are designated by means of Roman capitals. A brief description of the latter may take the place of the generic name in enabling the reader to understand the figures.

Organism A is a transparent jointed tube, about $\frac{1}{200}$ of an inch in length and $\frac{1}{1500}$ of an inch in thickness. It generally consists, as in Fig. 40, Pl. I, of four chambers, separated by three partitions; the middle one of which is single, and the two others double. The walls of each chamber are distinctly double, the ends of the tube being open and armed with two spines. The chambers contain grains, as of food, irregularly distributed. This four-chambered tube, which is the form of the organism most commonly observed, may result from the conjugation of two two-chambered ones, several of the latter having been seen alone. Six, and even eight, chambered ones were also noticed; but in these cases the double partitions were absent, as well as the food granules, though the spines were persistent.

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*If the practical question had been the construction of an ordinary canal, the specimens show that no obstacle exists to the successful prosecution of the work. The clays of strata 11 and 12 are of a depth and firmness that guarantee the permanence of the canal when once completed. In but two of the borings, Nos. 6 and 9, are they underlaid by sand at a depth likely to be reached by the dredgings, and even here, in No. 6, the sand contains enough clay to render it firm, while that in No. 9, though cleaner, cannot be considered a quicksand in its upper portion.

Organism B, Fig. 41, Pl. I, is a jointed filament, apparently flat, about $\frac{1}{1800}$ of an inch in breadth and $\frac{1}{400}$ in length. These joints are from four to six in number, shorter than the breadth of the filament, and chambered; the chambers being a little nearer to one side of the joint than the other.

Organism C, Fig. 42, Pl. I, is a cylindrical jointed tube, $\frac{1}{300}$ of an inch in breadth, and of a length dependent upon the number of joints. Each joint is shorter than the breadth of the filament, and has a simple contour; but within each joint are granules, irregularly arranged, generally around the walls of the joint, but sometimes against the partitions. The ends of the tube are closed.

Organism D, Fig. 43, Pl. I, is a sphere, not transparent, and of a somewhat rough contour. One side displays a rough and dark-colored depression. The diameter is about $\frac{1}{200}$ of an inch.

Organism E, Fig. 44, Pl. I, resembles the sash of a window. Each pane, so to speak, is a rectangular cell, transparent, with double walls, and is filled within with indistinct granules of a greenish hue. Only two rows are represented in the figure, but as many as five have been observed.

Organism F, Fig. 45, Pl. I, is shaped like an acid carboy. It is greenish in hue and translucent. The neck of the carboy is delicately lipped, and the body appears to hold a curved partition and other indistinct contents beneath. It is $\frac{1}{280}$ of an inch in diameter.

Organism G, Fig. 46, Pl. I, is similar in shape to the last, but larger, measuring $\frac{1}{140}$ of an inch in diameter. The neck is prolonged into a long, tapering, and slightly-curved filament. The body contains a number of egg-shaped bodies, transparent, and greenish in hue.

Organism H, Fig. 47, looks like an oat, well bearded upon one side, with delicate spines. It is colorless and transparent, and measures about $\frac{1}{480}$ of an inch in length.

Organism I, Fig. 48, is of the same greenish translucent appearance as F and G, and may be fancifully compared to a pair of breeches with a hat-brim for a waistband, and with legs that end in closed, tapering, and forked processes. Dark granules, apparently of clay, seem to have washed into these processes through the open waistband end.

Organism J is like a conical hat with a narrow brim. The latter is greenish and translucent, but the sides of the conical crown have radiating lines of *foramina*. It measures $\frac{1}{112}$ of an inch across the brim.

Annexed will be found the tabulated details of my observations, with the lists and plates of the microscopic organisms. A study of these will show a very general prevalence of fresh-water forms, even in strata obviously of marine formation. This was to be expected in deposits near the mouth of a great river, whose waters must be always sweeping the exuviæ of its own inhabitants out into the sea. Some of the strata, viz, Nos. 2, 7, 9, 10, and 11, seem to have been formed out of reach of salt water; but no marine stratum is free from influence of the fresh. In the sea-marsh stratum, No. 12, the proportion of marine forms is greater near the lake than farther back, probably because they were introduced by the tide. In the subjacent stratum, No. 8, the same phenomenon is noticeable, though in a less degree. Could it also have once been at the sea-level, and subjected to intermittent tidal influence? If so, has it sunk from the decay and disappearance of its vegetable matter? A process of this kind would have gone on unequally in different parts of the stratum, being affected by the porosity of the superincumbent layers, and would have left it at higher levels under the clays of Nos. 12 and 11 than under the sand-bed No. 9, as we see is the case.

But theorizing belongs rather to your department of our task. Trusting that the facts that I have accumulated may prove of service, I have the honor to subscribe myself,

Yours, very respectfully,

F. V. HOPKINS.

Prof. E. W. HILGARD.

APPENDIX III.

DETAILED RECORD OF EXAMINATION OF SPECIMENS OF BORINGS.

MICROSCOPIC CHARACTERS BY F. V. HOPKINS; LARGER ORGANISMS BY E. W. HILGARD.

BORING No. 1.

	Depth of specimens. *Feet.*	No. of decantations used in washing.	Peculiarities of the grains of quartz.	Mica.	Tourmaline.	Vegetable matter.	Microscopic organisms.
Stratum No. 11.—A bluish, drab-colored clay; non-calcareous; fresh-water.	5 to 10	2	Clear, *round*, and sharp; not over $.06^{mm}$ in diameter.	Little; not over $.05^{mm}$.	In crystals; rare; black.	Very little; rolled.	Fragillaria sp. undetermined, No. 1.
Stratum No. 8.—A blue clay, reddish where exposed; effervesces with acids; fresh-water.	10 to 20	3	Clear and red; rounded; not over $.06^{mm}$ in diameter.	Not over $.16^{mm}$.	None......	Much macerated.	Spongolithis mesogongyla, Ehr.
	20 to 30	3	Clear, red, and green; not over $.1^{mm}$ in diameter.	Brown and gray.	Black and crystallized.	Large pieces, macerated.	Spongolithis acicularia, Ehr. Lithostylidium denticulatum, Ehr.
	30 to 43	3	....do	....do	....do	....do	None.
	43 to 53	2	Clear $.05^{mm}$ down.	....do	....do	....do	Do.
	53 to 63	2	Clear, *rounded*, and sharp; $.16^{mm}$ in diameter and less.	....do	....do	....do	Lithostylidium sp. undetermined, No. 1. Synedra acuta, Ehr. Melosira sp. undetermined, No. 1. C and D, undetermined.
	63 to 73	3	Clear, rounded; not over $.08^{mm}$ in diameter.	....do	None......	Very little ..	Melosira sp. undetermined, No. 1.
Stratum No. 4.—Greenish-white sand; marine.	73 to 80	1	Clear, rounded; not over $.25^{mm}$ in diameter.	None......	None......	None........	Shell fragments abundant. Echinoid spines, Mellita sp. Grammostomum sp. undetermined, No. 1. Lithostylidium denticulatum, Ehr. Melosira sp. undetermined, No. 1.
	80 to 90	1	....do	....do	....do	....do	Do.

Stratum No. 4, 90 to 95 feet. Strongly micaceous sand, with little clay. Shells mostly very young.

Larger organisms.—Stratum No. 4, 72 to 95 feet.—Crab carapace. Balanus eburneus. Serpula sp. Nassa acuta Say. Anachis avara. Oliva mutica. Natica pusilla. Turbonilla interrupta. T. speira. Scalaria angulata. Marginella limatula. Dentalium n. sp. (laeve). Utriculus biplicatus. Teredo n. sp. Pandora trilineata. Mactra lataralis. Tellina alternata. T. tenera. T. tenta. Macoma fusca. Tellidora lunulata. Donax variabilis. Dosinia discus. Lucina multilineata. L. costata. Arca transversa. Glottidia pyramidata. Mellita testudinata. Cellepora n. sp. (1).

Macerated stems of Scirpus lacustris.

BORING No. 1—Continued.

	Depth of specimens.	No. of decantations used in washing.	Peculiarities of the grains of quartz.	Mica.	Tourmaline.	Vegetable matter.	Microscopic organisms.
Stratum No. 1.—A very firmly caked drab-colored clay; marine.	95 to 100	5	Clear; not over .1^{mm} in diameter.	A little .1^{mm} down.	None......	None........	Fragillaria sp. undetermined, No. 1.

Stratum No. 1, 95 to 100 feet.—Bluish-drab, rather dark clay; quite sandy. Shell fragments moderately abundant, large.

Larger organisms.—Nassa acuta. Utriculus biplicatus. Mactra lateralis. Mellita testudinata. Blackened vegetable fiber.

BORING No. 2.

	Depth of specimens.	No. of decantations used in washing.	Character of the grains of quartz.	Mica.	Tourmaline.	Vegetable matter.	Microscopic organisms.
Stratum No. 11.—A bluish-drab clay, more sandy above than below; fresh-water; non-calcareous.	*Feet.* 5 to 10	2	Clear, rounded and sharp; not over .08^{mm} in diameter.	A little....	An occasional black crystal.	None........	None.
	10 to 17	2	Clear brown and yellow; size as above.	More than above.	Not noted.	A little, rounded, abundant.	Fragillaria sp. undetermined, No. 2.
	17 to 28	2	Very few, small, clear, & rounded; .0016^{mm} in diameter and less.	A little; .005^{mm} in diameter.	....do	Macerated & rounded.	Fragillaria sp. undetermined, No. 1. Spongolithis acicularis, Ehr. Spongolithis aspera, Ehr. Lithostylidium quadratum, Ehr. Xanthidium? sp. undetermined, No. 1.
	28 to 38	3	Few, clear, *rounded*, and sharp; not over .1^{mm} in diameter; chalcedony in small proportion in smooth cubic grains.	Very little.	None......	Very abundant in largepieces, macerated.	Spongolithis acicularis, Ehr. Spongolithis mesogongyla, Ehr. Eunotia sp. undetermined, No. 1. Synedra sp. undetermined, No. 1. Leptocystinema Kinahani, Archer.
Stratum No. 8.—A caking, bluish-drab clay; effervesces with acids; organisms a mixture of marine and fresh-water forms.	38 to 48	3	Clear, sharp; not over .1^{mm} in diameter; green grains not infrequent.	Abundant, clear, gray, and red.	A little; black and crystallized.	A good deal, partly macerated and partly carbonized.	Lithostylidium denticulatum, Ehr.
	48 to 58	3	....do	....do	....do	....do	Do.
	58 to 68	3	Clear, with a little smoky quartz, and chalcedony; not over .1^{mm} in diameter.	Moderate in am't.	Not noted .	Not noted ...	Melosira sp. undetermined, No. 1. Grammostomum sp. undetermined, No. 1. Lithostylidium denticulatum, Ehr. Lithostylidium quadratum, Ehr. Cyclotella near punctata, S. Synedra acuta, Ehr.

Stratum 4, 68 to 82 feet. Greenish, strongly micaceous, sharp sand. Shells rather abundant, well preserved.

Larger organism.—Crab carapace. Balanus eburneus. Nassa acuta. Anachis avara. Oliva mutica. Natica pusilla. Acus dislocatum. Dentalium n. sp. (laeve). D. n. sp. (sexangulare). Teredo n. sp. Pholas costata. Pandora trilineata. Corbula cuneata. Tellina alternata. T. tenera. Chione cancellata. Ch. cribraria. Dosinia discus. Lucina multilineata. L. Costata. Cardium magnum? C. n. sp. (æquilaterale), C. n. sp. (inæquilaterale). Lævicardium Mortoni. Arca transversa. Pecten dislocatum? Mellita testudinata. Cellepora n. sp. (1).

BORING No. 3.

	Depth of specimens.	No. of decantations used in washing.	Characteristics of the quartz grains.	Mica.	Tourmaline.	Vegetable matter.	Microscopic organisms.
	Feet.						
Stratum No. 11.—A bluish clay; non-calcareous; fresh-water.	5 to 11	8	Clear; yellow and black; rounded and sharp; not over .1^{mm} in diameter.	Very little.	None......	very little; fresh and macerated.	Fragillaria capucina.
	11 to 23	8	....do..............	A little....	Crystallized	A little....	Rhizosolenia? sp. undetermined, No. 1. Two others undetermined.
	23 to 30	4	....do..............	...do......	A few black crystals.	Abundant; macerated.	Fragillaria capucina. Navicula sp. undetermined, No. 1. Lithostylidium sp. undetermined, No. 1. Spongolithis acicularis, Ehr. Organism undetermined, A.
Stratum No. 8.—A blue clay; calcareous; fresh-water.	30 to 38	8	Clear and rounded; size not above .08^{mm} in diameter.	A little....	A few black crystals.	Moderately plenty, in flattened pieces.	Cocconema lanceolatum, Ehr. Synedra sp. undetermined, No. 1. Undetermined, A and B.
	38 to 49	4	....do..............	...do......	...do......	...do......	Lithostylidium quadratum, Ehr. Melosira? sp. undetermined, No. 2, A and B.
	49 to 59	4	Clear, with some yellow grains; not over .05^{mm} in diameter; rounded and sharp in equal proportions.	...do......	A few clear crystals; also the black.	...do......	Fragillaria capucina. Fragillaria sp. undetermined, No. 1. Spongolithis acicularis, Ehr. Lithostylidium denticulatum, Ehr. A, B, and D.
	59 to 69	8	....do..............	...do......	Not noted..	Very little.	A.
	72	3	Some grains reach .16^{mm} in diameter.	...do......	Dark crystals.	Very little; fresh and macerated.	Lithostylidium denticulatum, Ehr. Melosira sp. undetermined, No. 1, A and B.
Stratum No. 4.—Greenish sand; marine or fluvio-marine.	72 to 82	1	Clear, rounded and sharp; not over .25^{mm} in diameter.	Not noted.	A few black crystals.	None......	Shell fragments abundant. Navicula sp. undetermined, No. 1. Eunotia? sp. undeterm'd, No. 1. Rotalia sp. undetermin'd, No. 1, A and B.
	82 to 92	1	Clear, rounded and sharp; not over .25^{mm} in diameter, with some brown and greenish grains.	Abundant, not over .7^{mm} in diameter.	None......	...do......	Shell fragments and Echinoid spines abundant. Grammastomum sp. undetermined, No. 2. Fragillaria sp. undeterm'd, No. 2. B and C, undetermined. Spongolithis acicularis, Ehr.
	96	1	Clear, size as above; grains rounded.	A little....	...do......	...do......	Shell fragments and Echinoid spines abundant.
	97	1	....do..............	...do......	...do......	...do......	None noted.

Stratum No. 4, 72 to 97 feet. Greenish micaceous sand coarse above, growing finer downward. Shell fragments rather abundant, but to a great extent very small and much worn, so as to be difficult to identify. Browned vegetable fragments especially in lower portion, and shell fragments larger.

Large organism.—Squalidean tooth. Crab carapace. Balanus eburneus. Serpula, n. sp. Nassa acuta. Anachis avara. Oliva mutica. Natica pusilla. Marginella limatula. Scalaria angulata. Architectonica gemma. Cylichna sp. Dentalium, n. sp. (læve). Dent., n. sp. (sexangulare). Dactylina oblonga. Pholas costata. Pandora trilineata. Corbula cuneata. Solen viridis. Mactra lateralis. Tellina alternata. T. tenera. Tellidora lunulata. Chione cribraria. Dosinia discus. Tapes pygmæa. Astarte lunulata. Lucina multilineata. L. costata. Cardium, n. sp. (æquilaterale). C., n. sp. (inæquilaterale). Lævicardium Mortoni. Arca transversa. Pecten dislocatum. Anomia ephippium. Glottidia pyramidata. Mellita testudinata. Cellepora, n. sp. (1).

BORING No. 3—Continued.

	Depth of specimens.	No. of decantations used in washing.	Peculiarities of quartz grains.	Mica.	Tourmaline.	Vegetable matter.	Microscopic organisms.
Stratum No. 1.—a firmly caked drab-colored clay; marine.	*Feet.* 97 to 100	3	Clear, with some yellow, green, and black gra.; not over $.1^{mm}$ in diameter; *sharp*.	None......	None	None......	Orbulina universa, d'Orb. Globigerina bulloides, d'Orb. Rossilina beccarii, d'Orb.

Stratum No. 1, 97 to 100 feet. Dark gray, very heavy and plastic clay; disintegrates very slowly on boiling, but settles rapidly, showing much rather coarse sand. Shell fragments numerous, quite large, much worn. Much blackened vegetable bast and fiber.

Larger organism.—Balanus eburneus. Oliva mutica. Natica pusilla. Pandora trilineata. Mactra lateralis. Tellina alternata. Chione cancellata. Ch. cribraria. Lucina multilineata. Cardium, n. sp. (æquilaterale). Lævicardium Mortoni. Arca transversa. Arca ponderosa. Leda acuta. Mellita testudinata. Cellepora, n. sp. (1).

BORING No. 4.

	Depth of specimens.	No. of decantations used in washing.	Characteristics of the grains of quartz.	Mica.	Tourmaline.	Vegetable matter.	Microscopic organisms.
Stratum No. 11.—A bluish drab-colored clay; non-calcareous; fresh-water.	*Feet.* 5 to 10	3	Clear, rounded and sharp, some red; not over $.05^{mm}$ in diameter.	A little....	An occasional black crystal.	Moderate in amount; macerated.	Synedra acuta? Ehr.
	10 to 22	3	......do	....do	....do	....do	Xanthidium? sp. undetermined, No. 1. Leptocystinema? sp. undetermined, No. 1.

BORING No. 4—Continued.

	Depth of specimens.	No. of decantations used in washing.	Characteristics of the grains of quartz.	Mica.	Tourmaline.	Vegetable matter.	Microscopic organisms.
Stratum No. 8.—A caking bluish-drab clay; effervesces with acids; fresh-water.	22 to 32	4	Clear, sharp and rounded; not over .16$^{\text{mm}}$ in diameter.	A little....	Not noted..	Macerated in pieces. 3 in. in diameter.	Leptocystinema Kinahani, Archer. Synedra acuta? Ehr.
	32 to 42	2	......do	....do	....do	Very little...	None.
	42 to 52	2	......do	....do	....do	....do	None noted.
	56	2	......do	....do	....do	....do	Do.
	56 to 64	2	......do	Abundant.	....do	....do	Do.
Stratum No. 4.—A greenish micaceous sand; marine.	64 to 73	1	Clear, rounded; not over .25$^{\text{mm}}$ in diameter.	A little....	None.......	None........	Shell fragments abundant.
	73 to 91	1	Clear, rounded; not over .25$^{\text{mm}}$ in diameter; some ferruginous conglomerate grains.	....do	....do	....do	Do.

Larger organism.—Stratum 4, 64 to 91 feet.

Balanus eburneus. Mangelia filiformis? Natica pusilla. Turbonilla interrupta? Dentalium, n. sp. (sexangulare). Cylichna sp. Pholas costata. Pandora trilineata. Tellina alternata. T. tenera. Chione cribraria. Dosinia discus. Lucina multilineata. Cardium, n. sp. (æquilaterale). Arca transversa. Mellita testudinata. Cellepora (1).

Stratum No. 1, 91 to 100 feet. Tough bluish-gray clay, leaving but little sand on sieve, but quite sandy. Shell fragments tolerably abundant and large. Little mica, some browned vegetable fiber.

Corbula cuneata. Tellina alternata. Tellidora lunulata. Dosinia discus. Lucina multilineata. Lævicardium Mortoni. Arca transversa. Pecten dentatus. Mellita testudinata.

BORING No. 5.

	Depth of specimens.	No. of decantations used in washing.	Characteristics of the grains of quartz.	Mica.	Tourmaline.	Vegetable matter.	Microscopic organisms.
	Feet.						
Stratum No. 11.—A bluish-drab colored clay; non-calcareous; fresh-water.	5 to 10	4	Clear, rounded, and sharp; not over .16$^{\text{mm}}$ in diameter.	None......	None......	Abundant; macerated.	Spongolithis acicularis, Ehr. Fragillaria sp. undetermined, No. 1. Leptocystinema? sp. undetermined, No. 1. Nitzschia? sp. undetermined, No. 1. Fragillaria capucina. B.
	10 to 20	4	As above, but grains not over 1$^{\text{mm}}$ in diameter.	A little....	....do	In excess....	Fragillaria sp. undetermined, No. 1. Fragillaria capucina. A and B.

BORING No. 5—Continued.

	Depth of specimens.	No. of decantations used in washing.	Characteristics of the grains of quartz.	Mica.	Tourmaline.	Vegetable matter.	Microscopic organisms.
Stratum No. 10.—A blue clayey sand; calcareous; fresh-water.	*Feet.* 20 to 30	3	Clear, with some black grains; not over .15^{mm} in diameter.	None......	A few black crystals.	In excess; carbonized.	A and B.
Stratum No. 9.—A bluish sand, slightly clayey; calcareous; fresh-water.	30 to 45	1	Clear and brownish-yellow; not above .1^{mm} in diameter; sharp and rounded.	Abundant, clear, and yellow.	None......	Abundant; carbonized and fresh.	A and B.
Stratum No. 8.—A bluish-drab clay; calcareous; fresh-water above, a few marine shells below.	45 to 53	3	Clear and rounded; not over .04^{mm} in diameter.	Abundant.	None......	Abundant; macerated.	Fragillaria sp. undetermined, No. 2. Navicula sp. undetermined, No. 3. A and B.
	53 to 57	3	Clear, with many black and yellow grains; not over .15^{mm} in diameter.	....do	....do	Abundant; macerated and black.	A and B.

Larger organisms.—The specimen from 53 to 57 feet. A tough, bluish-gray clay. Boiled and washed through the sieve, leaves on the latter but a very little rounded quartz sand, some fragments of ferruginous conglomerate, a few mica scales, many blackened vegetable fragments, very few of shells. Among the latter, Tellina alternata, T. tenta, and fragments and spicules of mellita testudinata were recognized.

BORING No. 5—Continued.

	Depth of specimens.	No. of decantations used in washing.	Peculiarities of the quartz grains.	Mica.	Tourmaline.	Vegetable matter.	Microscopic organisms.
Stratum No. 4.—A greenish-white sand; marine or fluvio-marine.	*Feet.* 57 to 67	1	Clear, rounded, and sharp; not over .25^{mm} in diameter.	Abundant.	A few black crystals.	A little; partly carbonized.	Shell fragments abundant. Echinoid spines 2 species undeterm'd. Truncatulina (lobulata? d'Orb.).
	67 to 72	1	....do	....do	....do	....do	Shell fragments abundant. Echinoid spines 2 species undeterm'd. Nonionina sp. undetermined. Spongolithis acicularis, Ehr. Fragillaria capucina. A and B.

Larger organisms.—In the yellowish-drab, highly micaceous sand of stratum No. 4, 57 to 72 feet, shell fragments are quite abundant but small; some blackened vegetable remains. Sand grains mostly so large as to remain on the sieve, and rather sharp. Balanus eburneus. Serpula, n. sp. Nassa acuta. Anachis avara. Oliva mutica. Pleurotoma cerinum? Mangelia filiformis? Turbonilla, n. sp. (undecimsulcata). Obeliscus crenulatus. Utriculus biplicatus. Pholas costata. Pandora trilineata. Corbula cuneata. Mactra lateralis. Tellina alternata. T. tenera. T. tenta. Macoma fusca. Chione cancellata. Ch. cribraria. Dosinia discus. Lucina multilineata. L. costata. Cardium, n. sp. (æquilaterale). Ch., n. sp. (inæquilaterale). Arca transversa. Pecten dislocatus. Mellita testudinata. Cellepora, n. sp. (1).

BORING No. 5—Continued.

	Depth of specimens.	No. of decantations used in washing.	Peculiarities of the quartz grains.	Mica.	Tourmaline.	Vegetable matter.	Microscopic organisms.
Stratum No. 3.—A smooth yellowish-drab clay; non-effervescent with acids; fluvio-marine.	*Feet.* 72 to 78	5	Clear, rounded, and sharp; not over $.25^{\mathrm{mm}}$ in diameter.	Abundant.	A few black crystals.	None	Hyalonema ? sp. undetermined. Nonionina (crassula ?) d'Orb. Spongolithis acicularis, Ehr. Spongolithis aspera, Ehr. Spongolithis mesogongyla, Ehr. Fragillaria sps. undetermined, 1 and 2. Fragillaria capucina. Lithostylidium sp. undetermined, No. 1. A and B.

Stratum No. 3, 72 to 78 feet. A yellowish-white, very pure and tough clay, difficult to disintegrate by boiling. Washed on sieve, leaves little sand; white, very sharp sand goes through. The clay water does not settle for a long time, showing absence of lime-salts. Shells scarce.

Larger organisms.—Balanus eburneus. Mactra lateralis. Macoma fusca. Chione cribraria. Lævicardium Mortoni. Arca transversa. Mellita testudinata.

BORING No. 5.—Continued.

	Depth of specimens.	No. of decantations used in washing.	Peculiarities of the quartz grains.	Mica.	Tourmaline.	Vegetable matter.	Microscopic organisms.
Stratum No. 2.—A yellowish-drab sand; calcareous; fluvio-mar'e.	*Feet.* 78 to 90	1	Clear, with many yellow grains; not over $.25^{\mathrm{mm}}$ in diameter.	Not noted.	A few black crystals.	Fresh and macerated; abundant.	Spongolithis appendiculata, Ehr. Spongolithis acicularis, Ehr. Fragillaria capucina. A and B.
	90 to 100	....	......do	....do	....do	....	Shell fragments.

Stratum No. 2, 78 to 100 feet. Yellowish-drab sand, usually coarse above, fine below; numerous grains of ferruginous conglomerate. Shells rare, in large fragments.

Larger organisms.—Nassa acuta. Oliva mutica. Corbula cuneata. Solen viridis. Mactra lateralis. Tellina alternata. Chione cribraria. Dosinia discus. Lucina multilineata. Arca ponderosa. Anomia ephippium. Mellita testudinata.

BORING No. 6.

	Depth of specimens.	No. of decantations used in washing.	Characteristics of the grains of quartz.	Mica.	Tourmaline.	Vegetable matter.	Microscopic organisms.
Stratum No. 11.—A bluish clay; non-calcareous; fresh-water.	*Feet.* 5 to 10	4	Clear; not over $.16^{mm}$ in diameter; rounded oftener than sharp.	None......	None......	Abundant, macerated and rounded.	Spongolithis acicularis. Fragillaria sp. undetermined No. 1.
Stratum No. 10.—A blue, clayey sand; calcareous; fresh-water.	10 to 20	3	Clear, with a few black grains; not over $.25^{mm}$ in diameter; rounded and sharp.	Very little.	None.......	Abundant, but less so than above.	None noted.
Stratum No. 9.—A drab-colored sand; calcareous; fresh-water.	20 to 30	1	Clear, yellow and brown; not over $.16^{mm}$ in diameter; sharp and rounded.	Moderate..	None.......	Moderate, macerated.	None noted.
	35 to 40	1	......do	Abundant.	A little.....	....do	Cocconema lanceolatum, Ehr.
Stratum No. 8.—A bluish clay, sandy above; calcareous; fluvio-marine.	40 to 50	3	Clear, rounded; not over $.05^{mm}$ in diameter; some green grains.	A little....	None.......	A little, with an odor of sulphur.	Spongolithis acicularis, Ehr. Melosira sp. undetermined, No. 1. Rosalina Beccarii, d'Orb.
	50 to 59	3	Clear, *sharp*, oftener than rounded; not over $.05^{mm}$ in diameter; many green grains.	Moderate..	A few crystals, with one of actinolite & one of vivianite.	A little......	Conferva-like green grains. Spongolithis sp. undetermined, No. 1. Navicula sp. undetermined, No. 4. B.

Stratum No. 4, 59 to 81 feet. Greenish sand with large mica scales, very little clay. Shell fragments small and difficult to determine. Splinters of white wood, seemingly cottonwood.

Larger organisms.—Crab claw. Balanus eburneus. Serpula, n. sp. Urosalpinx cinereus. Nassa acuta. Anachis lunata. Oliva mutica. Mangelia linearis? Pleurotoma cerinum. Natica pusilla. Marginella limatula. Volva acicularis. Dentalium, n. sp. (laeve). Cylichna sp. Pholas costata. Pandora trilineata. Corbula cuneata. Solen viridis. Mactra lateralis. Tellina alternata. T. tenera. Tellidora lunulata. Chione cribraria. Dosinia discus. Lucina multilineata. L. costata. Cardium, n. sp. (aequilaterale). Laevicardium Mortoni. Arca transversa. A. pexata. Mellita testudinata. Cellepora, n. sp. (1).

Stratum No. 3, 81 to 85 feet. Bluish gray, stiff clay, not easily disintegrated by boiling. No shells or sand left on the sieve, but much browned bark and wood fragments.

BORING NO. 7.

	Depth of specimens.	No. of decantations used in washing.	Characteristics of the grains of quartz.	Mica.	Tourmaline.	Vegetable matter.	Microscopic organisms.
	Feet.						
Stratum No. 11.—A bluish-drab colored clay; non-effervescent with acids; fresh-water.	5 to 10	4	Clear, rounded; not over $.1^{mm}$ in diameter.	Moderate in am't.	In clear crystals.	A little macerated.	None.
	10 to 20	2	Clear, rounded; not over $.25^{mm}$ in diameter.	Abundant.	Green, striated crystals.	Rounded and macerated.	Do.
Stratum No. 8.—A bluish, sandy clay; calcareous; fresh-water.	20 to 29	2	Clear, rounded; not over $.25^{mm}$ in diameter; also a little chalcedony in smooth cubic grains.	None noted	Both clear and green.	Moderately abundant; rounded & macerated.	Lithostylidium denticulatum, Ehr. Cyclops n. quadricornis.
	29 to 34	1	Variegated, clear, milky, black, red, and brown; not over $.75^{mm}$ in diameter.	Very little.	Not noted	Pieces large, carbonized, and fresh.	None noted.
Stratum No. 7.—A coarse, gray sand, calcareous; fresh-water.	34 to 45	1	Clear, rounded; not over $.25^{mm}$ in diameter; black and green grains occasionally.	A little....	None......	None........	None.
	45 to 57	1	....do............	....do.....	....do.....	....do.......	Do.
	57 to 67	1	....do............	....do.....	....do.....	....do.......	Do.
	67 to 72	1	....do............	....do.....	....do.....	....do.......	Do.

Stratum No. 4, 72 to 87 feet. Bluish gray, rather fine, clayey and micaceous sand; shell fragments, large, few.

Larger organisms.—Balanus eburneus. Nassa acuta. Dentalium ? n. sp. (læve). Tellina alternata. Pholas costata. Corbula cuneata. Mactra lateralis. Tellidora lunulata. Chione cancellata. Ch. cribraria. Lucina multilineata. L. costata. Cordium, n. sp. (æquilaterale.) Lævicardium Mortoni. Mellita testudinata.

Stratum No. 3 (?), 87 to 88 feet. Dark-colored clay, tough, evidently originally laminated, with layers variously colored and constituted; very difficult to disintegrate. Washed on sieve, it leaves numerous and large blackened peaty fragments, mica scales, a few large rounded grains of pellucid quartz, fragments of ferruginous sandy conglomerate, and a few indistinct shell fragments, seemingly of Mactra lateralis and Tellina tenera.

Stratum No. 2, 88 to 100 feet. Fine bluish, rather clayey sand; quartz grains much rounded; some particles of ferruginous conglomerate.

Larger organisms.—Turbonilla acicula. Corbula cuneata. Tellina alternata. Chione cribraria. Dosinia discus. Lucina costata. Lævicardium Mortoni. Mellita testudinata.

BORING No. 8.

	Depth of specimens.	No. of decantations used in washing.	Characteristics of the grains of quartz.	Mica.	Tourmaline.	Vegetable matter.	Microscopic organisms.
Stratum No. 11.—A bluish-drab colored clay; non-calcareous; fresh-water.	*Feet.* 5 to 16	2	Clear, rounded; not over $.1^{mm}$ in diameter; red-spotted grains and some carnelian.	Little.....	None.....	Very little; macerated.	None.
	17 to 22	2	Clear, with some red and red-spotted; not over $.1^{mm}$ in diameter.	....do.....	Green, in 9-sided crystals.	....do......	One undetermined. C.
	22 to 32	2	Clear, rounded; not over $.25^{mm}$ in diameter.	....do.....	Not noted.	Moderate in amount.	None.
Stratum No. 8.—A blue clay; calcareous; fluvio-marine.	32 to 41	2	Clear, rounded, and sharp; not over $.1^{mm}$ in diameter.	Abundant; plates large.	Green striated.	Abundant; macerated.	Rosalina Beccarii.
	41 to 54	2	Clear, with some red and green grains; not above $.1^{mm}$ in diameter.	Abundant; plates large; $.16^{mm}$ in diameter.	....do.....	....do......	Lithostylidium denticulatum, Ehr. Coscinodiscus radiatus, Ehr. Melosira sp. undetermined, No. 1.
	54 to 63	2	Clear, with a few red-spotted grs.; not over $.25^{mm}$ in diameter.	A little....	....	Very little; macerated and rolled.	Melosira sp. undetermined, No. 1.

Stratum No. 4, 63 to 77 feet. Greenish-drab sand, micaceous, much rounded, a little coarser below than above; very little clay; much browned vegetable remains.

Larger organisms.—Balanus eburneus. Anachis avara. Oliva mutica. Turbonilla interrupta. Cæcum pulchellum. Scalaria angulata. Dentalium n. sp. (læve). D., n. sp. (sexangulare). Pholas costata. Corbula cuneata. Colbula n. sp.?. Solen viridis. Mactra lateralis. Tellina alternata. Chione cribraria. Dosinia discus. Lucina multilineata. Cardium n. sp. (æquilaterale). C., n. sp. (inæquilaterale). Arca transversa. Lima sp. Anomia ephippium. Mellita testudinata. Cellepora, n. sp. (1).

Stratum No. 3, 77 to 79 feet. Leaden-blue clay, rather sandy, micaceous, easily disintegrated, some fragments of bark.

Larger organisms.—Nassa acuta. Turbonilla interrupta. Scalaria lineata. Pholas costata. Corbula cuneata. Mactra lateralis. Chione cancellata. Ch. cribraria. Lucina multilineata. L. costata. Arca transversa. A. ponderosa. Anomia ephippium. Mellita testudinata.

BORING No. 9.

	Depth of specimens.	No. of decantations used in washing.	Characteristics of the grains of quartz.	Mica.	Tourmaline.	Vegetable matter.	Microscopic organisms.
Stratum No. 12.—Dark brown clay, non-calcareous; a swamp mud, dark from excess of vegetable matter, with many fresh-water and a few marine organisms.	*Feet.* 5 to 10	2	Few and clear; not over .03$^{\text{mm}}$ in diameter.	None....	None....	Abundant; macerated.	Orbulina universa, d'Orb. Planulina n. elegans, Ehr. Rotalia n. pachyphysa, Ehr. Melosira sp. undetermined, No. 3. Pinnularia n. gigas. Ehr. Synedra acuta. Ehr. Synedra sp. undetermined, No. 1. Navicula sp. undetermined, No. 5. Spongolithis sp. undetermined, No. 1. Spongolithis acicularis, Ehr. Spongolithis aspera, Ehr. Spongolithis inflexa, Ehr. Fragillaria sp. undetermined, No. 1. Fragillaria capucina. B.
Stratum No. 11.—A bluish-drab colored clay; non-calcareous; fresh-water.	11 to 15	2	Few, clear, and green; not over .1$^{\text{mm}}$ in diameter.	A little..	A few crystals.	Abundant but less than above.	Synedra acuta?. Ehr. Spongolithis acicularis, Ehr.
Stratum No. 10—A blue clayey sand; calcareous; fresh-water.	15 to 24	1	Clear, with a few with red spots; rounded and sharp both; a little Chalcedony in smooth cubic grains; not over .25$^{\text{mm}}$ in diameter.	A little..	None....	A little, macerated.	Lithostylidium denticulatum, Ehr.
Stratum No. 9.—A drab-colored sand; calcareous; fresh-water.	24 to 35	1	Clear, with a few yellow and brown grains; not over .25$^{\text{mm}}$ in diameter.	A little..	None....	A little, macerated.	Lithostylidium denticulatum, Ehr.
Stratum No. 8.—A blue clay, sandy above; calcareous.	35 to 50	2	Clear and red, spotted, rounded, and sharp; not over .25$^{\text{mm}}$ in diameter; a little Chalcedony.	A little..	None....	A little, macerated.	Lithostylidium denticulatum, Ehr.
	50 to 59	3	Clear, with a few red and blue grains; not over .1$^{\text{mm}}$ in diameter.	...do	...do	None..........	None.
	59 to 64	...	....do	...do	...do	....do	Do.

BORING No. 10—Continued.

	Depth of specimens.	No. of decantations used in washing.	Characteristics of the grains of quartz.	Mica.	Tourmaline.	Vegetable matter.	Microscopic organisms.
	Feet.						
Stratum No. 4.—A greenish sand; marine and fresh-water organisms, both present, but the former much the more numerous.	55 to 70	1	Clear, with few grains of carnelian, amethyst, and silicified wood, not over .1^{mm} in diameter.	A little.	A few crystals.	None ...	Shell fragments abundant. Orbulina universa, d'Orb. Pleurosigma sp. undetermined, No. 3. Cocconeis scutellum, Ehr. Pinnularia n. macilenta, Ehr. Navicula sp. undetermined No. 4. Galllionella (Melosira), distana, Ehr. Fragillaria capucina. Fragillaria sp. undetermined, Nos. 1 and 2.

Larger organisms.—Balanus eburneus. Oliva mutica. Busycon perversus. Utriculus biplicatus. Spirorbis sp. Dentalium, n. sp. (læve). Pandora trilineata. Corbula cuneata. Solen viridis. Mactra lateralis. Tellina polita? Strigilla flexuosa. Tellidora lunulata. Chione cribraria. Astarte lunulata. Lucina multilineata. L. costata. L. Kiawahensis. Cardium, n. sp. (æquilaterale). Lævicardium Mortoni. Arca transversa. Anomia ephippium. Mellita testudinata. Cellepora, n. sp. (1). Cellepora, n. sp. (2)

BORING No. 11.

	Depth of specimens.	No. of decantations used in washing.	Characteristics of the grains of quartz.	Mica.	Tourmaline.	Vegetable matter.	Microscopic organisms.
	Feet.						
Stratum No. 12.—A black swamp clay; non-effervescent with acids; vegetable matter in excess; organisms both fresh-water and marine.	5 to 15	3	Clear, rounded; not over .1^{mm} in diameter.	Very little.	A few black crystals.	In excess, macerated.	Campylodiscus sp. undetermined, No. 1. Rotalia sp. undetermined, No. 2. Spongolithis acicularis, Ehr. Lithostylidium denticulatum. Spongolithis acicularis, Ehr. One undetermined, I.
	20 to 25	3	....do	..do	Not noted...	....do	

BORING NO. 10.

	Depth of specimens.	No. of decantations used in washing.	Characteristics of the grains of quartz.	Mica.	Tourmaline.	Vegetable matter.	Microscopic organisms.
	Feet.						
Stratum No. 12.—A blue clay, dark with vegetable matter; non-calcareous; many fresh-water organisms, with a few marine.	5 to 10	4	Clear, rounded; not over .1^{mm} in diameter.	Not noted	Not noted	Abundant, macerated.	Orbulina universa, d'Orb. Hyalodiscus cervinus, Brightwell. A, B, and E. Spongolithis sp. undetermined, No. 1. Spongolithis acicularis. Ehr. Lithostylidium denticulatum, Ehr. Lithostylidium n. quadratum. Closterium sp. undetermined, No. 1.
Stratum No. 8.—A blue clay; calcareous; more fresh-water organisms than marine in the upper part, more marine than fresh-water below.	10 to 25	4	Clear, with a few red and yellow grains; from .25^{mm} in diameter down.	Not noted	Not noted	Abundant, macerated.	Melosira sp. undetermined, 1 and 4. Eunotia n. gibberula, Ehr. Spongolithis sp. undetermined, No. 2. Fragillaria capucina. Fragillaria sp. undetermined, No. 2. A and B.
	25 to 35	4	Clear, with some carnelian, sharp; not over .1^{mm} in diameter.	...do	...do	....do	Orbulina universa, d'Orb. Triceratium favus, Ehr. Pleurosigma sp. undetermined, No. 1. Rotalia sp. undetermined, No. 1. Melosira sp. undetermined, No. 5. Melosira n. sulcata, Ehr. A.
	35 to 45	4	Clear, rounded, and sharp; not over .1^{mm} in diter.	...do	...do	Moderately plenty.	Hyalodiscus cervinus, Brightwell. Orbulina universa, d'Orb. Melosira n. sulcata, Ehr. Melosira sp. undetermined, 6 and 7. Gallionella distans, Ehr. Pleurosigma sp. undetermined, No. 2. Navicula n. Grundleri, Ad. Schmidt. Navicula sp. undetermined, No. 6. Cocconeis sp. undetermined, No. 1. Pinnularia macilenta, Ehr. Spongolithis sp. undetermined, No. 2. A and B. Closterium sp. undetermined, No. 2. Fragillaria capucina.
Stratum No. 6.—Fine, crumbling, grayish clay; calcareous; organisms few, fresh-water and marine.	45 to 55	3	Clear, rounded; not over .022^{mm} in diameter.	None....	None....	A little........	Shell fragments few. Spongolithis sp. undetermined, No. 2. A and B.

Larger organisms.—Abundance of macerated and partly blackened vegetable remains, apparently chiefly of grasses and rushes. Numerous very young shells, irrecognizable. Balanus eburneus. Mactra lateralis. Arca transversa. Lucina multilineata.

BORING No. 10—Continued.

	Depth of specimens.	No. of decantations used in washing.	Characteristics of the grains of quartz.	Mica.	Tourmaline.	Vegetable matter.	Microscopic organisms.
Stratum No. 4.—A greenish sand; marine and fresh-water organisms, both present, but the former much the more numerous.	*Feet.* 55 to 70	1	Clear, with few grains of carnelian, amethyst, and silicified wood, not' over .1^{mm} in diameter.	A little.	A few crystals.	None ...	Shell fragments abundant. Orbulina universa, d'Orb. Pleurosigma sp. undetermined, No. 3. Cocconeis scutellum, Ehr. Pinnularia n. macilenta, Ehr. Navicula sp. undetermined No. 4. Galllonella (Melosira), distans, Ehr. Fragillaria capucina. Fragillaria sp. undetermined, Nos. 1 and 2.

Larger organisms.—Balanus eburneus. Oliva mutica. Busycon perversus. Utriculus biplicatus. Spirorbis sp. Dentalium, n. sp. (læve). Pandora trilineata. Corbula cuneata. Solen viridis. Mactra lateralis. Tellina polita? Strigilla flexuosa. Tellidora lunulata. Chione cribraria. Astarte lunulata. Lucina multilineata. L. costata. L. Kiawahensis. Cardium, n. sp. (æquilaterale). Lævicardium Mortoni. Arca transversa. Anomia ephippium. Mellita testudinata. Cellepora, n. sp. (1). Cellepora, n. sp. (2)

BORING No. 11.

	Depth of specimens.	No. of decantations used in washing.	Characteristics of the grains of quartz.	Mica.	Tourmaline.	Vegetable matter.	Microscopic organisms.
Stratum No. 12.—A black swamp clay; non-effervescent with acids; vegetable matter in excess; organisms both fresh-water and marine.	*Feet.* 5 to 15	3	Clear, rounded; not over .1^{mm} in diameter.	Very little.	A few black crystals.	In excess, macerated.	Campylodiscus sp. undetermined, No. 1. Rotalia sp. undetermined, No. 2. Spongolithis acicularis, Ehr. Lithostylidium denticulatum. Spongolithis acicularis, Ehr. One undetermined, I.
	20 to 25	3	....do	.:.do	Not noted...	....do	

BORING NO. 11—Continued.

	Depth of specimens.	No. of decantations used in washing.	Characteristics of the grains of quartz.	Mica.	Tourmaline.	Vegetable matter.	Microscopic organisms.
Stratum No. 8.—A sandy blue clay; effervesces with acids; organisms few; more marine than fresh-water.	*Feet.*						
	30 to 35	2	Clear, rounded, and sharp; not over .1mm in diameter.	Abundant	None	None	Campylodiscus sp. undetermined, No. 1. Coscinodiscus radiatus. Melosira sp. undetermined, No. 1 Spongolithis acicularis, Ehr.
	48 to 52	2	....do	...do	....do	....do	Do.

Stratum 4, 52 to 70 feet. Grayish, very micaceous, rather coarse-looking sand, with numerous entire shells and shell fragments, the most abundant in the set. Although styled "quicksand" by the borers, it contains many grains and pebbles of clay, so as to render it difficult to separate it all. Sand grains much rounded, often partly conglomerated by a ferruginous cement.

Larger organisms.—Balanus eburneus. Serpula sp. Urosalpinx cinereus. Nassa acuta. Anachis avara. Oliva mutica. Obeliscus crenulatus. Cæcum pulchellum. Architectonica gemma. Acus dislocatum. Modulus Floridanus. Cochliolepis parasitica. Crepidula fornicata. Dentalium, n. sp. (læve). Dent., n. sp. (sexangulare). Utriculus biplicatus. Pholas costata. Pandora trilineata. Corbula cuneata. Solen viridis. Mactra lateralis. Tellina alternata. T. polita. Strigilla flexuosa. Donax variabilis. Chione cancellata. Ch. cribraria. Astarte lunulata. Lucina multilineata. L. costata. L. Kiawahensis. Cardium, n. sp. (inæquilaterale). Arca transversa. A. ponderosa. Modiola sp. Anomia ephippium. Mellita testudinata. Cellepora, n. sp. (1). Cellepora, n. sp. (2).

BORING No. 12.

	Depth of specimens.	No. of decantations used in washing.	Characteristics of the grains of quartz.	Mica.	Tourmaline.	Vegetable matter.	Microscopic organisms.
Stratum No. 12.—Swamp clay, black with vegetable matter; organisms, both marine and fresh-water, in excess.	*Feet.* 5 to 15	3	Clear, rounded, and sharp; not over .125mm in diameter.	Very little.	A few black crystals.	Very large amount; carbonized and fresh.	Campylodiscus sp. undetermined, No. 1. Rotalia sp. undetermined, No. 2. Melosira (Gallionella) distans, Ehr. Melosira sp. undetermined, No. 8. Pinnularia viridula, Ehr. Cocconema lanceolatum, Ehr. Lithostylidium denticulatum, Ehr. Synedra acuta, Ehr. Spongolithis acicularis, Ehr. Fragillaria sp. undetermined, No. 1. Closterium sp. undetermined, No. 3. Two others undetermined, E and F.
	15 to 26	3	....do	A little....	...do	...do	Campylodiscus sp. undetermined, No. 2. Rotalia sp. undetermined, No. 2. Orbulina universa, d'Orb. Melosira sp. undetermined, No. 1. Pinnularia viridula, Ehr. Navicula fulva?, Ehr. Lithostylidium denticulatum, Ehr. Spongolithis acicularis, Ehr. A and B. Cypris? Two others undetermined, E and F.
Stratum No. 6.—A sandy blue clay; calcareous; organisms few, and more marine than fresh-water.	26 to 40	3	Clear, with a few grains of sillicified wood; not over .1mm in diameter.	Abundant.	A few black crystals.	A little, macerated.	Rotalia sp. undetermined, No. 1. One undetermined, n. Coscinodiscus. Spongolithis acicularia, Ehr. A.
	40 to 55	2	Clear, rounded, and sharp; not over .08mm in diameter.	...do	None......	....do	Pleurosigma sp. undetermined, No. 4. Melosira sp. undetermined, No. 1.
Stratum No. 5.—A sandy laden blue clay, easily disintegrated; calcareous; marine, with a very few fresh-water organisms.	55 to 71	3	Clear, rounded; not over .5mm in diameter.	Abundant.	A few black crystals with some actinolite.	A little, macerated.	Rosalina Beccarii, d'Orb. Truncatulina (lobulata?), d'Orb. Planulina n. elegans, Ehr. Globigerina n. depressa, Ehr. Orbulina n. universa, d'Orb. Grammostomum sp. undetermined, No. 1 Campylodiscus sp. undetermined, No. 1. Coscinodiscus radiatus, Ehr. Triceratium reticulatum, Ehr. Navicula n. Grundleri, Ad. Schmidt. Spongolithis acicularis, Ehr. Spongolithis n. anchora, Ehr. Spongolithis n. aspera, Ehr. Fragillaria sp. undetermined, No. 1. Shell fragments abundant. Echinoid spines.

Larger organisms.—Balanus eburneus. Nassa acuta. Oliva literata. Natica pusilla. Scalaria lineata. Pholas costata. Pandora trilineata. Corbula cuneata. Mactra lateralis. Tellina alternata. T. tenera. Strigilla flexuosa. Chione cribraria. Tapes pygmæa. Cardium, n. sp. (æquilaterale). Lævicardium Mortoni. Lucina (Codakia?) n. sp. Arca transversa. Mellita testudinata.

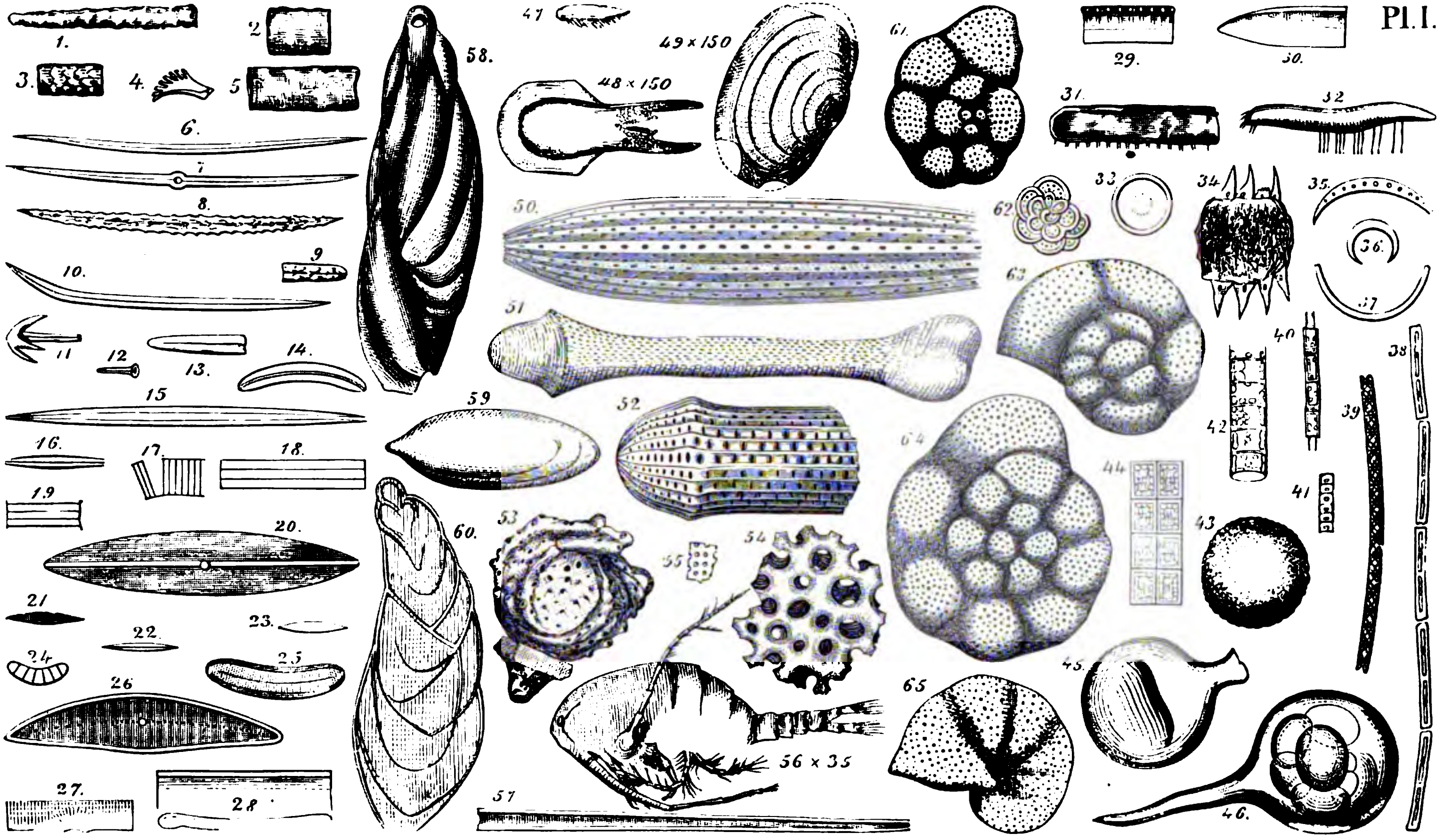
BORING NO. 13.

	Depth of specimens.	No. of decantations used in washing.	Characteristics of the grains of quartz.	Mica.	Tourmaline.	Vegetable matter.	Microscopic organisms.
Stratum No. 12.—Swamp clay, black with vegetable matter; more marine than fresh-water organisms.	*Feet.* 5 to 15	3	Clear, rounded, and sharp; not over .16^{mm} in diameter.	Very little.	A few black crystals.	In excess; macerated.	Campylodiscus sp. undetermined, No. 1. Melosira sp. undetermined, No. 1. Cyclotella n. punctata, Ad. Schmidt. Lythostylidium denticulatum, Ehr. E. undetermined. Navicula sp. undetermined, No. 7.
	15 to 25	3	....do	....do	....do	....do	Do.
Stratum No. 8.—A blue clay; calcareous; more marine than fresh-water organisms.	30 to 35	2	Clear, sharp; not over .08^{mm} in diameter.	Moderate in amount.	None......	Abundant....	Lenticulum n. discus, Ehr. Grammostomum n. Americanum, Ehr. Melosira sp. undetermined, Nos. 1 and 9. Navicula sp. No. 7. Spongolithis acicularis.
	35 to 45	2	Clear, with some yellow and brown grains and silicified wood; not over .16^{mm} in diameter.	Moderate in am'nt; some plates studded with garnets.	A little green striated.	....do	None noted.
	45 to 56	2	Clear, sharp; not over .08^{mm} in diameter.	Moderate in am'nt.	None......	....do	Cyclotella n. punctata, Ad. Schmidt. Melosira sp. undetermined, No. 1, abundant.

Stratum No. 4, 56 to 69 feet. Fine greenish quartzose sand, moderately micaceous, grains both sharp and rounded. Shell fragments abundant, but small and mostly irrecognizable. Much macerated wood and fragments of Scirpus.

Larger organisms.—Balanus eburneus. Nassa acuta. Anachis avara. Mangelia sp. Oliva mutica. Natica pusilla. Obeliscus crenulatus. Dentalium, n. sp. (læve). Dent., n. sp. (sexangulare). Teredo sp. Pandora trilineata. Corbula cuneata. Mactra lateralis. Tellina tenera. Chione cribraria. Dosinia discus. Venus mercenaria. Astarte undulata. Lucina multilineata. L. costata. L. crenulata. L. Kiawahensis. Cardium, n. sp. (æquilaterale). Mellita testudinata.

Pl. I.



F. W. Hopkins, M. D., New Almaden, Del.

A. KRUGER, S. F., Eng.

BORING NO. 14.

	Depth of specimens.	No. of decantations used in washing.	Characteristics of the grains of quartz.	Mica.	Tourmaline.	Vegetable matter.	Microscopic organisms.
Stratum No. 12.—Swamp clay, black with vegetable matter; organisms very abundant, more marine than fresh-water.	*Feet.* 5 to 15	3	Clear, rounded, and sharp; not over .13mm in diameter.	Very little.	A few black crystals.	In excess ...	Campylodiscus sp. undetermined, No. 1. Melosira sp. undetermined, No. 1. Cyclotella sp. undetermined, No. 1. Globigerina sp. undetermined, No. 1. Nitzschia? sp. undetermined, 2, 3, and 4. Navicula sp. undetermined No. 8. Rhizosolenia sp. No. 2. Synedra acuta, Ehr. Spongolithis acicularis, Ehr. Spongolithis aspera, Ehr. Lithostylidium denticulatum, Ehr. Lithostylidium crispum, Ehr. E, H, G, and I undetermined.
	20 to 25	3	....do	....do	....do	....do	Do.
Stratum No. 8.—A blue clay, sandy; calcareous; organisms few, but more marine than fresh-water	25 to 35	3	Clear, rounded, and sharp; not over .1mm in diameter.	Abundant	A few black crystals.	A little, macerated.	None noted.
	35 to 45	3	....do	....do	None......	....do	Do.
	45 to 56	3	....do	....do	....do	....do	Campylodiscus sp. No. 1. Melosira sp. undetermined, No. 1. Spongolithis acicularis, Ehr. Lithostylidium denticulatum, Ehr. I and J undetermined.

Stratum No. 4, 56 to 70 feet. Greenish sand, same as in boring 13 at same depths.

Larger organisms.—Balanus eburneus. Nassa acuta. Oliva mutica. Marginella limatula. Cæcum pulchellum. Dentalium? n. sp. (læve). Dent., n. sp. (sexangulare). Pholas costata. Corbula cuneata. Mactra lateralis. Tellina alternata. Tellidora lunulata. Chione cribraria. Dosinia discus. Lucina multilineata. L. costata. Lævicardium Mortoni. Arca transversa. A. pexata. A. ponderosa. Pinna muricata. Mellita testudinata. Cellepora, n. sp. (1).

APPENDIX IV.

LIST OF MICROSCOPIC ORGANISMS FOUND IN BORINGS, WITH TWO PLATES, BY F. V. HOPKINS.

LIST OF FRESH-WATER ORGANISMS.

[To front Plate I.]

[The figures represent the objects magnified 300 diameters, unless otherwise marked on the plates.]

Fig. 1. Lithostylidium denticulatum, Ehr. Occurs in Borings 1, 2, 3, 7, 8, 9, 10, 11, 12, 13, and 14, and in Strata 4, 8, 9, 10, and 12.
Fig. 2. Lithostylidium quadratum, Ehr., in Borings 2 and 3. Strata 11 and 8.
Fig. 3. Lithostylidium n. quadratum, Ehr. Boring 10. Stratum 12.
Fig. 4. Lithostylidium crispum, Ehr. Boring 14. Stratum 12.
Fig. 5. Lithostylidium sp. undet., 1. Borings 1, 3, and 5. Strata 8, 11, and 3.
Fig. 6. Spongolithis acicularis, Ehr. Borings 1, 2, 3, 5, 6, 9, 10, 11, 12, 13, and 14. Strata 2, 3, 4, 5, 8, 11, and 12.
Fig. 7. Spongolithis mesogongyla, Ehr. Borings 1, 2, and 5. Strata 8, 11, and 13.

Fig. 8. Spongolithis n. aspera, Ehr. Borings 2, 5, 9, and 14. Strata 3, 11, and 12.
Fig. 9. Spongolithis n. aspera, Ehr. Boring 12. Stratum 5.
Fig. 10. Spongolithis inflexa, Ehr. Boring 9. Stratum 12.
Fig. 11. Spongolithis anchora, Ehr. Boring 12. Stratum 5.
Fig. 12. Spongolithis appendiculata, Ehr. Boring 5. Stratum 2.
Fig. 13. Spongolithis sp. undet., No. 1. Borings 6, 9, and 10. Strata 8 and 12.
Fig. 14. Spongolithis sp. undet., No. 2. Borings 10 and 2. Strata 8, 6, and 11.
Fig. 15. Synedra acuta? Ehr. Borings 1, 2, 4, 9, 12, and 14. Strata 8, 11, and 14.
Fig. 16. Synedra sp. undet., No 1. Borings 2, 3, and 9. Strata 11, 8, and 12.
Fig. 17. Fragillaria capucina. Borings 3, 5, 9, and 10. Strata 2, 3, 4, 8, 11, and 12.
Fig. 18. Fragillaria sp. undet., No. 1. Borings 1, 2, 3, 5, 6, 9, 10, and 12. Strata 1, 3, 4, 5, 8, 11, and 12.
Fig. 19. Fragillaria sp. undet., No. 2. Borings 2, 3, 5, and 10. Strata 3, 4, 8, and 11.
Fig. 20. Navicula sp. undet., No. 1. Boring 3. Strata 11 and 4.
Fig. 21. Navicula sp. undet., No. 3. Boring 5. Stratum 8.
Fig. 22. Navicula sp. undet., No. 4. Borings 6 and 10. Strata 8 and 4.
Fig. 23. Navicula sp. undet., No. 5. Boring 9. Stratum 12.
Fig. 24. Eunotia n. gibberula, Ehr. Boring 10. Stratum 8.
Fig. 25. Eunotia sp. undet. Borings 2 and 3. Strata 11 and 4.
Fig. 26. Cocconema lanceolatum, Ehr. Borings 3, 6, and 12. Strata 8, 9, and 12.
Fig. 27. Nitzschia? sp. undet., No. 1. Boring 5. Stratum 11.
Fig. 28. Nitzschia? sp. undet., No. 2. Boring 14. Stratum 12.
Fig. 29. Nitzschia sp. undet., No. 3. Boring 14. Stratum 12.
Fig. 30. Nitzschia sp. undet., No. 4. Boring 14. Stratum 12.
Fig. 31. Rhizosolenia? sp. undet., No. 1. Boring 3. Stratum 11.
Fig. 32. Rhizosolenia? sp. undet., No. 2. Boring 14. Stratum 12.
Fig. 33. Gallionella (Melosira Ag.) distans, Ehr. Borings 10 and 12. Strata 8, 4, and 12.

Desmids.

Fig. 34. Xanthidium? sp. undet., No. 1. Borings 2 and 4. Stratum 11.
Fig. 35. Closterium sp. undet., No. 1. Boring 10. Stratum 12.
Fig. 36. Closterium sp. undet., No. 2. Boring 10. Stratum 8.
Fig. 37. Closterium sp. undet., No. 3. Boring 12. Stratum 12.
Fig. 38. Leptocystinema Kinahani, Archer. Borings 2 and 4. Strata 8 and 11.
Fig. 39. Leptocystinema? sp. undet. Borings 4 and 5. Stratum 11.

Incertæ sedis.

Fig. 40. A. Borings 3, 5, 10, and 12. Strata, 2, 3, 4, 6, 8, 9, 10, 11, 12.
Fig. 41. B. Borings 3, 5, 6, 9, 10, and 12. Strata 2, 3, 4, 6, 8, 9, 10, 11, 12.
Fig. 42. C. Borings 1 and 8. Strata 8 and 11.
Fig. 43. D. Borings 1 and 3. Stratum 8.
Fig. 44. E. Borings 10, 12, 13 and 14. Stratum 12.
Fig. 45. F. Boring 12. Stratum 12.
Fig. 46. G. Boring 14. Stratum 12.
Fig. 47. H. Boring 14. Stratum 12.
Fig. 48. I. Boring 14. Stratum 8.
Fig. 49. J. Boring 14. Stratum 8. An infant *Codakia?*

LIST OF SALT AND BRACKISH WATER ORGANISM.

Radiates.

Fig. 50. Echinoid spine sp. undet., No. 1. Boring 3. Stratum 4.
Fig. 51. Echinoid spine sp. undet., No. 2. Boring 5. Stratum 4.
Fig. 52. Echinoid spine sp. undet., No. 3. Borings 1, 5, 9, and 12. Strata 4 and 5.
Fig. 53. Coral sp. undet., K. Boring 3. Stratum 4.
Fig. 54. Coral sp. undet., L. Boring 5. Stratum 4.
Fig. 55. Coral sp. undet., M. Boring 10. Stratum 4.

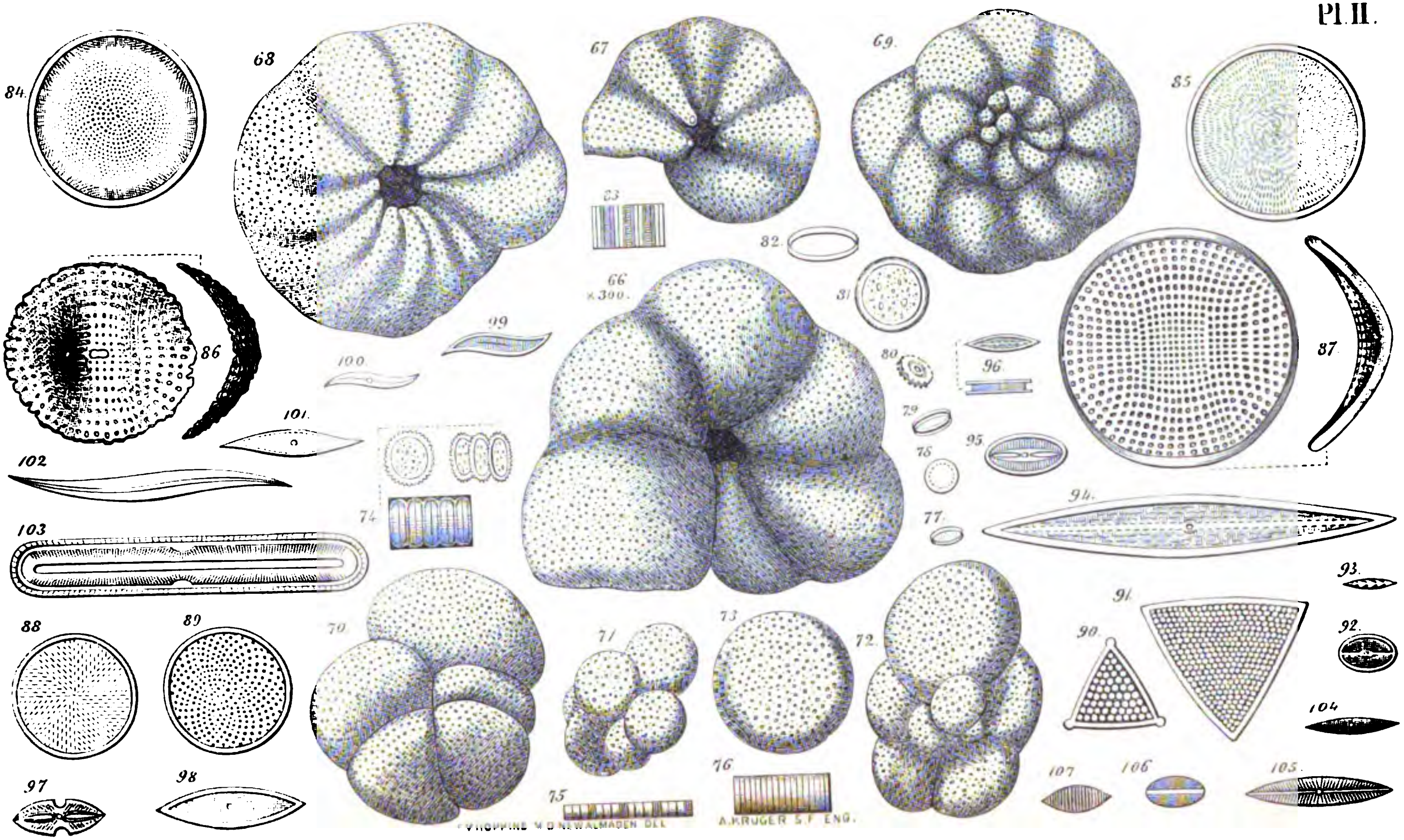
Articulate.

Fig. 56. Cyclops n. quadricornis. Boring 7. Stratum 8.

Sponge.

Fig. 57. Hyalonema? sp. undet. Boring 5. Stratum 3.

Pl. II.



E. V. HOPPINE M. D. NEWALMADEN DEL. A. KRUGER S. F. ENG.

Foraminifera.

Fig. 58. Grammostomum sp. undet., No. 1. Borings 1, 3, 12. Strata 4, 5, and 8.
Fig. 59. Grammostomum ? sp. undet., No. 2. Boring 3. Stratum 4.
Fig. 60. Grammostomum n. Americanum, Ehr. Boring 13. Stratum 8.
Fig. 61. Rotalia n. pachyphysa, Ehr. Boring 9. Stratum 12.
Fig. 62. Rotalia sp. undet., No. 1. Borings 3, 10, and 12. Strata 4 and 8.
Fig. 63. Rotalia sp. undet., No. 2. Borings 11 and 12. Stratum 12.
Fig. 64. Rosalina Beccarii, d'Orb. Borings 3, 6, 8, and 12. Strata 1, 8, and 5.
Fig. 65. Truncatulina (lobulata ? d'Orb.). Borings 5 and 12. Strata 4 and 5.

[To front Plate II.]

Fig. 66. Planulina n. elegans, Ehr. Borings 9 and 12. Strata 12 and 5.
Fig. 67. Nonionina (crassula ? d'Orb). Boring 5. Stratum 3.
Fig. 68. Nonionina sp. undet. Boring 5. Stratum 4.
Fig. 69. Lenticulum n. discus., Ehr. Boring 13. Stratum 8.
Fig. 70. Globigerina bulloides, d'Orb. Boring 3. Stratum 1.
Fig. 71. Globigerina n. depressa., Ehr. Boring 12. Stratum 5.
Fig. 72. Globigerina sp. undet. Boring 14. Stratum 12.
Fig. 73. Orbulina universa ? d'Orb. Borings 3, 9, 10, and 12. Strata 1, 4, 5, 8, and 12.

Diatoms.

Fig. 74. Melosira sp. undet., No. 1. Borings 1, 2, 3, 6, 8, 10, 11, 12, 13, 14. Strata 4, 8, and 12.
Fig. 75. Melosira sp. undet., No. 2. Boring 3. Stratum 8.
Fig. 76. Melosira sp. undet., No. 3. Boring 9. Stratum 12.
Figs. 77, 78, 79, 80. Melosiræ sps. undet., Nos. 4, 5, 6, and 7. Boring 10. Stratum 8.
Fig. 81. Melosira sp. undet., No. 8. Boring 12. Stratum 12.
Fig. 82. Melosira sp. undet., No. 9. Boring 13. Stratum 8.
Fig. 83. Melosira sp. n. sulcata, Ehr. Boring 10. Stratum 8.
Fig. 84. Cyclotella n. punctata, Ad. Schmidt. Borings 2 and 13. Strata 12 and 8.
Fig. 85. Cyclotella sp. undet. Boring 14. Stratum 12.
Fig. 86. Campylodiscus sp. undet., No. 1. Borings 11, 12, 13, and 14. Strata 5, 8, 11, and 12.
Fig. 87. Campylodiscus sp. undet., No. 2. Boring 12. Stratum 12.
Fig. 88. Hyalodiscus cervinus ? Brightwell. Boring 10. Strata 8 and 12.
Fig. 89. Coscinodiscus radiatus ? Ehr. Borings 8, 11, and 12. Strata 8 and 5.
Fig. 90. Triceratium favus, Ehr. Boring 10. Stratum 8.
Fig. 91. Triceratium reticulatum, Ehr. Boring 12. Stratum 5.
Fig. 92. Navicula sp. undet., No. 2. Boring 3. Stratum 4.
Fig. 93. Navicula sp. undet., No. 6. Boring 10. Stratum 8.
Fig. 94. Navicula sp. undet., No. 7. Boring 9. Stratum 12.
Fig. 95. Navicula sp. undet., No. 8. Boring 14. Stratum 12.
Fig. 96. Navicula sp. undet., No. 9. Boring 13. Strata 8 and 12.
Fig. 97. Navicula sp. n. Grundleri, Ad. Schmidt. Boring 12. Stratum 5.
Fig. 98. Navicula (fulva ? Ehr.) Boring 12. Stratum 12.
Figs. 99, 100. Pleurosigma sps. undet., Nos. 1 and 2. Boring 10. Stratum 8.
Fig. 101. Pleurosigma sp. undet., No. 3. Boring 10. Stratum 4.
Fig. 102. Pleurosigma sp. undet., No. 4. Boring 12. Stratum 8.
Fig. 103. Pinnularia n. gigas, Ehr. Boring 9. Stratum 12.
Fig. 104. Pinnularia macilenta, Ehr. Boring 10. Strata 8 and 4.
Fig. 105. Pinnularia viridula, Ehr. Boring 12. Stratum 12.
Fig. 106. Cocconeis sp. undet., No. 1. Boring 10. Stratum 8.
Fig. 107. Cocconeis (scutellum ? Ehr.) Boring 10. Stratum 4.

APPENDIX V.

SYNOPTICAL TABLE OF THE "LARGER ORGANISMS" FOUND IN THE BORINGS. NOTES ON FOSSILS. BY E. W. HILGARD.

Synoptical table of "larger organisms" occurring in the Lake Borgne survey borings.

	Boring.																												
	No. 1.		No. 2.	No. 3.		No. 4.		No. 5.			No. 6.		No. 7.			No. 8.		No. 9.				No. 10.		No. 11.	No. 12.	No. 13.	No. 14.	New Orleans well, 1856.
	Stratum 4, 73 to 95 feet.	Stratum 1, 95 to 100 feet.	Stratum 4, 68 to 82 feet.	Stratum 4, 72 to 97 feet.	Stratum 1, 97 to 100 feet.	Stratum 4, 64 to 91 feet.	Stratum 1, 91 to 100 feet.	Stratum 4, 57 to 72 feet.	Stratum 3, 72 to 78 feet.	Stratum 2, 78 to 100 feet.	Stratum 4, 59 to 81 feet.	Stratum 3, 81 to 85 feet.	Stratum 4, 72 to 87 feet.	Stratum 3, 87 to 88 feet.	Stratum 2, 88 to 100 feet.	Stratum 4, 63 to 77 feet.	Stratum 3, 77 to 80 feet.	Stratum 4″, 64 to 73 feet.	Stratum 4′, 73 to 80 feet.	Stratum 4, 80 to 91 feet.	Stratum 1, 91 to 100 feet.	Stratum 6, 45 to 55 feet.	Stratum 4, 55 to 70 feet.	Stratum 4, 53 to 70 feet.	Stratum 5, 55 to 75 feet.	Stratum 4, 56 to 69 feet.	Stratum 4, 56 to 70 feet.	
Squalidean tooth	—	—	—	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Crab carapace, fragments	+	—	+	—	—	—	—	—	—	—	+	—	—	—	—	—	—	+	+	—	—	—	—	—	—	—	—	—
Cypris sp.?	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—	—
Balanus eburneus (?)	+	—	+	+	+	+	—	+	+	—	+	+	+	—	—	+	—	—	+	+	+	+	+	—	+	+	+	+
Serpula n. sp.?	+	—	—	+	—	—	—	+	—	—	+	+	—	—	—	—	—	+	+	—	—	—	—	+	—	—	—	—
Ranella caudata, Say	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—	—	—	—	—	—	—	+
Fasciolaria distans, Lam.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+
Sycotypus canaliculatus, Linn.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+
Sycotypus perversus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—	—	—
Urosalpinx cinereus, Say	—	—	—	—	—	—	—	—	—	—	+	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—	—
Nassa acuta, Say	+	+	+	+	—	—	—	+	—	+	+	—	+	—	—	—	+	+	+	+	+	—	—	+	+	+	+	+
Anachis avara, Say	+	—	+	+	—	—	—	+	—	—	—	—	—	—	—	+	—	+	—	—	—	—	—	+	—	+	—	—
Anachis lunata, Say	—	—	—	—	—	—	—	—	—	—	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Oliva literata, Say	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	+
Oliva mutica, Say	+	—	+	+	+	—	—	+	—	+	+	—	—	—	—	+	—	+	+	+	+	—	+	+	—	+	+	+
Pleurotoma cerinum, K. and St.	—	—	—	—	—	—	—	+	—	—	—	—	—	—	—	—	—	+	—	—	—	—	—	—	—	—	—	+
Mangelia filiformis, Holm.	—	—	—	—	—	+	—	+	—	—	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Natica pusilla, Say	+	—	+	+	+	+	—	—	—	—	+	—	—	—	—	—	—	+	—	—	—	—	—	—	+	+	—	+
Natica Campeachensis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+
Marginella limatula, Con.	+	—	—	+	—	—	—	—	—	—	+	—	—	—	—	—	—	—	+	+	—	—	—	—	—	—	+	+
Volva acicularis, H. and A.	—	—	—	—	—	—	—	—	—	—	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Turbonilla interrupta, H. and A.	+	—	—	—	—	—?	—	—	—	—	—	—	—	—	—	+	+?	—	—	—	—	—	—	—	—	—	—	—
Turbonilla speira, Rav.	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Turbonilla undecim-sulcata n. sp	—	—	—	—	—	—	—	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Turbonilla acicula, Holm.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—	—	—	—	—	—	—	—	—	—	—
Obeliscus crenulatus, Holm.	—	—	—	—	—	—	—	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	+	—	—
Caecum pulchellum, Stimp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—	—	—	—	—	+	—	—	+	.

Scalaria angulata, Say	+	—	—	+	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—	—	—	—	—	—	—	—	—	—
Scalaria lineata, Say	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+	+	—	—	—	—	—	—	+	—	—	—
Architectonica gemma, Holm	—	—	—	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—	—
Acus dislocatum, Say	—	—	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—	+
Modulus Floridanus, Con	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—	—
Crepidula fornicata, Linn	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—	+
Dentalium ? n. sp. (læve)	+	—	+	+	—	—	—	+	—	—	+	+	+	—	—	+	—	+	—	+	—	+	+	+	—	+	+	—
Dentalium n. sp. (sexangulare)	—	—	+	+	—	+	—	+	—	—	—	—	—	—	—	+	—	+	—	—	—	—	—	+	—	+	+	—
Cylichna sp.	—	—	—	+	—	+	—	—	—	—	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Utriculus (Tornatina) biplicatus, H. C. Lea	+	+	—	—	—	—	—	+	—	—	—	—	—	—	—	—	—	—	—	+	—	—	+	+	—	—	—	+
Teredo sp.	+	—	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—	—	—	—	—	+	—	—
Dactylina oblongata, Say	—	—	—	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—	—	—	—	—
Pholas costata, Linn	—	—	+	+	—	+	—	+	—	—	+	+	+	—	—	+	+	+	—	+	—	—	—	+	+	—	+	+
Pandora trilineata, Say	+	—	+	+	+	+	—	+	—	—	+	+	—	—	—	—	—	+	—	+	+	—	+	+	+	+	—	+
Corbula cuneata, Say	—	—	+	+	—	—	+	+	—	+	+	—	+	—	+	+	—	+	+	—	—	—	+	+	+	+	+	—
Corbula acuta ?	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—	—	—	—	—	—	—	—	—	—
Solen viridis, Say	—	—	—	+	—	—	—	—	—	+	+	+	—	—	—	+	—	—	—	—	—	—	+	+	—	—	—	—
Gnathodon cuneatus, Say	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+
Mactra lateralis, Say	+	+	—	+	+	—	—	+	+	+	+	—	+	+	—	+	+	+	+	+	+	+	+	+	+	+	+	+
Mactra Sayi, Con	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+
Tellina alternata, Say	+	—	+	+	+	+	+	+	—	+	+	+	+	—	+	+	—	+	+	+	—	—	—	+	+	—	+	+
Tellina polita, Say	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+	+	—	—	—	+
Tellina tenera, Say	+	—	+	+	—	+	—	+	—	—	+	+	—	+?	—	—	—	+	—	+	—	—	—	—	+	+	—	+
Tellina tenta, Say	+	—	—	—	—	—	—	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+
Strigilla flexuosa, Say	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+	+	+	—	—	+
Macoma fusca, Say	+	—	—	—	—	—	—	+?	+?	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Tellidora lunulata, Adams	+	—	—	+	—	—	+	—	—	—	+	+	+	—	—	—	—	—	+	—	—	—	+	—	—	—	+	+
Donax variabilis, Say	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—	+
Abra n. sp., Con.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+
Semele n. sp., Con.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+?	—	—	—	—	+
Chione cancellata, Linn.	—	—	+	—	+	—	—	+	—	—	—	—	+	—	—	—	+	—	—	—	+	—	—	+	—	—	—	+
Chione cribraria, Con.	—	—	+	+	+	+	—	+	+	+	+	+	+	—	+	—	+	—	—	+	+	—	+	+	+	+	+	+
Chione latilirata, Con. (C. paphia, Lam.)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+
Dosinia concentrica, Con. (D. discus Rve.)	+	—	+	+	—	+	+	+	—	+	+	—	—	—	+	+	—	+	+	+	—	—	—	—	—	+	+	+
Tapes pygmaea	—	—	—	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	+
Mercenaria violacea, Adams	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	+
Astarte lunulata, Con.	—	—	—	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+	+	—	—	—	+
Astarte undulata, Say	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	+	—	—	—	—	—	+	—	—
Lucina multilineata, Con.	+	—	+	+	+	+	+	+	—	+	+	—	+	—	—	+	+	+	+	—	+	+	+	+	—	+	+	+
L. costata, T. and H.	+	—	+	+	—	—	—	+	—	—	+	—	+	—	+	—	+	+	+	—	+	—	+	+	—	+	+	+
Lucina Kiawahensis, T. and H.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+	+	—	+	—	—
Lucina crenulata, Con.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—
Cardium magnum, Born	—	—	+?	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+
Cardium n. sp. ? (æquilaterale)	—	—	+	+	+	+	—	+	—	—	+	—	+	—	—	+	—	+	—	—	—	—	+	—	+	+	—	—
Cardium n. sp., Con. (inæquilaterale)	—	—	+	+	—	—	—	+	—	—	—	—	—	—	—	+	—	—	—	—	—	—	—	+	—	—	—	+
Lævicardium Mortoni, Con.	—	—	+	+	+	—	+	—	+	—	+	—	+	—	+	—	—	+	+	—	—	—	+	—	+	—	+	+
Arca transversa, Say	+	—	+	+	+	+	+	+	+	—	+	+	—	—	—	+	+	+	+	—	+	+	+	+	+	—	+	+
Arca pexata, Say	—	—	—	—	—	—	—	—	—	—	+	—	—	—	—	—	—	—	+	—	—	—	—	—	—	—	+	+
Arca ponderosa, Say	—	—	—	—	+	—	—	—	—	+	—	—	—	—	—	—	+	—	—	—	—	—	—	+	—	—	+	+
Arca Americana, Gray	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+
Leda acuta, Con.	—	—	—	—	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Modiola ?	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—	—

Synoptical table of "larger organisms" occurring in the Lake Borgne survey borings—Continued.

	Boring.																											
	No. 1.		No. 2.	No. 3.		No. 4.		No. 5.			No. 6.		No. 7.			No. 8.		No. 9.				No. 10.		No. 11.	No. 12.	No. 13.	No. 14.	New Orleans well, 1856.
	Stratum 4, 73 to 95 feet.	Stratum 1, 95 to 100 feet.	Stratum 4, 68 to 82 feet.	Stratum 4, 72 to 97 feet.	Stratum 1, 97 to 100 feet.	Stratum 4, 64 to 91 feet.	Stratum 1, 91 to 100 feet.	Stratum 4, 57 to 72 feet.	Stratum 3, 72 to 78 feet.	Stratum 2, 78 to 100 feet.	Stratum 4, 59 to 81 feet.	Stratum 3, 59 to 81 feet.	Stratum 4, 72 to 87 feet.	Stratum 3, 87 to 88 feet.	Stratum 2, 88 to 100 feet.	Stratum 4, 63 to 77 feet.	Stratum 3, 77 to 80 feet.	Stratum 4'', 64 to 73 feet.	Stratum 4', 73 to 80 feet.	Stratum 4, 80 to 91 feet.	Stratum 1, 91 to 100 feet.	Stratum 6, 45 to 55 feet.	Stratum 4, 55 to 70 feet.	Stratum 4, 52 to 70 feet.	Stratum 5, 55 to 75 feet.	Stratum 4, 56 to 69 feet.	Stratum 4, 56 to 70 feet.	
Pinna muricata, Linn.	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+	−
Lima sp.	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+?	−	−	−	−	−	−	−	−	−	−	−	−
Pecten dislocatus, Say	−	−	+?	+?	−	−	−	+?	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+
Pecten dentatus?	−	−	−	−	−	−	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+
Anomia ephippium, Linn.	−	−	−	+	−	−	−	−	−	+	−	−	−	−	−	+	+	+	+	−	−	−	+	+	−	−	−	+
Ostrea, 2 sp., undet.	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+
Glottidia pyramidata, Stimp	+	−	−	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
Mellita testudinata, Klein? or M. Caroliniana, Rav.	+	+	+	+	+	+	+	+	+	+	+	+	+	−	+	+	+	+	+	+	−	−	+	+	+	+	+	−
Cellepora sp. (1)	+?	−	+	+?	+	+	−	+	−	−	+	−	−	−	−	+	+	+	+	−	−	−	+	+	−	+	+	+
Cellepora sp. (2)	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+	−	−	−	−	+	+	−	−	−	+

NOTES ON THE LARGER FOSSILS FOUND IN THE BORINGS FOR THE LAKE BORGNE OUTLET.

Balanus eburneus.—The specimens of this somewhat tender species, occurring in nearly all the marine strata examined, are all so broken and worn as to render an absolute specific identification difficult. Its general shape could in no case be verified; but the structural characters, as far as observable, agree with those of *B. eburneus.*

Serpula "fenestrata," n. sp. ?—Of very general occurrence in the marine sands; minute; fragments rarely above 0.3^{mm} in length; sometimes two or three tubes longitudinally coherent. Canal orbicular, about 0.3^{mm} in diameter, smooth. Walls of about the same average thickness as the diameter of the canal exterior of four to five rough, irregular lamellar costæ, each forming a ridge between two rows of transverse rectangular cells, which, when worn, impart to the surface a fenestrated appearance. On the longitudinal section these cells appear subquadrate and twice the diameter of the solid portion of the tube-wall. Pl. III, Fig. 11*a*; *b*, worn fragment; *c* and *d*, horizontal and longitudinal sections.

Turbonilla undecim-sulcata, n. sp.—In form of spire, etc., resembles *T. 5-striata* Holmes. It differs in having eight revolving lines, one of which is double, and two broad furrows. One of the latter is at base, close to the shoulder, then four fine lines, of which the lowest is the double one; then (a little above the middle of the volution), the second broad furrow, then four more lines. Fig. 10, basal whorl, with magnified view of lines.

Utriculus (Tornatina) biplicatus.—This is the species named *Bullina canaliculata* in my report on the fossils of the New Orleans artesian well (Rep. U. S. Eng. Dept. for 1870). Upon examination of more numerous and perfect specimens in the present series, I identify the New Orleans specimens likewise with *U. biplicatus.*

Cylichna sp.—From the broken and much worn specimens found, I am unable to identify this shell positively with any of the described species. It comes nearest *C. oryza* Stimp. Pl. III, Fig. 14.

Architectonica gemma.—Although differing slightly in sculpture from Holmes's description, this can hardly be claimed as a new species. Pl. III, Fig. 9, basal and dorsal view. In the latter the prominence of the apical volution is not sufficiently shown.

Natica Campeachenis. Pl. III, Fig. 8.—Young shell, natural size. A careful comparison of this shell with a full suite of specimens from the West Indies establishes its identity. From the New Orleans artesian well of 1856.

Dentalium (Antalis)? "læve," n. sp. ?—Minute, almost straight, young shells, semi-transparent, very fragile, very abundant in some sediments; older ones opaque, porcelain-like; surface perfectly smooth and shining, with no trace of longitudinal striæ, but faintly-perceptible growth-lines. Apex rounded, imperforate, as observed in immature specimens of 2 to 3^{mm} length. Greatest length of fragment observed 6.75^{mm}, indicating about 10^{mm} as the length of the mature shell. The imperforate apex, if maintained in maturity, seems to separate this shell from *Antalis* and *Dentalium.* Pl. III, Fig. 6.

Dentalium "sexangulare," n. sp. ?—Larger than the preceding, but no perfect specimen seen. Shell rather thick, not shining, six-sided, with an elevated line midway on the faces; curved, especially toward the apex. Resembles strongly *D. alternatum* of the Mississippi eocene. Pl. III, Fig. 7; A, apex; C, basal cross-section.

Corbula cuneata.—"Rather more deeply and regularly ribbed than Say's figure, but clearly referrible to this very variable species." (R. E. C. Stearns.) Very abundantly and generally present in the strata examined, and somewhat unaccountably absent from the fossils of the New Orleans artesian well of 1856.

Astarte undulata Say. (?)—Not over 3.5^{mm} in diameter; agrees most nearly with this exceedingly variable species of Say.

Cardium "æquilaterale," n. sp. ?—Shell orbicular, perfectly equilateral; maximum length, 2.2^{mm}; profoundly radiately ribbed; ribs about 28 in number, obtuse on edge, nearly triangular in cross-section, smooth, except the last 5 or 6 posterior ones, which have distant, smooth, mamillary warts, very uniform in size, so as to appear to be an adult shell. Very abundant in some of the Lake Borgne specimens, but not observed in the New Orleans well series. In both suites, however, there occurs sparingly another minute species.

Cardium "inæquilaterale," n. sp., perfect specimens of which from New Orleans were forwarded by me to Mr. Conrad, and recognized as new, but not as yet described in consequence of having been mislaid. In general form it resembles *C. magnum*, but is distinguished by its minuteness and surface sculpture from all described species. No perfect specimen was found in the Lake Borgne suite; characteristic fragments are not uncommon, but none sufficient for figuring.

Strigilla (Tellina) flexuosa, Say.—One of the most abundant shells of the New Orleans series, is quite rare in the Lake Borgne suite.

Abra, n. sp. (*fide* Conrad, 1870).—A pretty species, abundant at some levels in the New Orleans artesian well, and to which some fragments found in the Lake Borgne borings may be referrible. Pl. III, Fig. 3.

Venus cuneimeris (*Circomphalus?*), Pl. III, Fig. 5.—Agrees with specimens from Florida collected by Mr. R. E. C. Stearns. Probably from the New Orleans artesian well of 1856, at 41 feet.

Tapes pygmæa.—Believed to be a new species by Mr. Conrad, to whom I transmitted specimens in 1870, but not described by him. The shell figured agrees altogether with Floridian specimens in the possession of Mr. Stearns. Pl. III, Fig. 1.

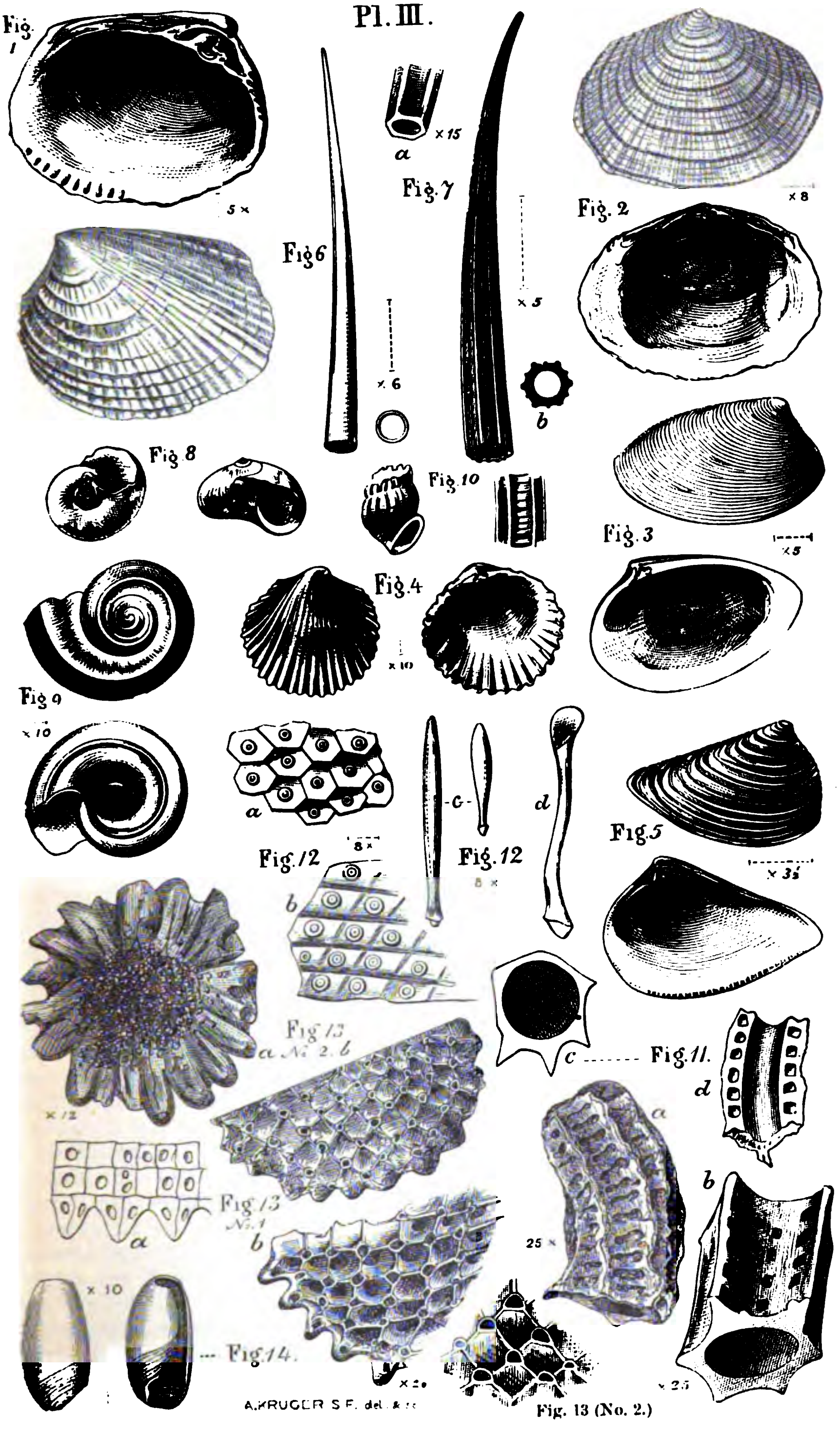
Lucina (*Codakia*), n. sp.?—Only one valve found, somewhat imperfect. Hinge showing two subtriangular pits separated by a thin, straight, vertical lamellar tooth. Shell much compressed, undulate, thick. Pl. III, Fig. 2.

Mellita testudinata, Klein?—None of the fragments found were large enough to ascertain distinctly its general outline or the existence of perforations. Professor Carpenter, in a note on specimens sent him by Mr. Forshey, determines the specimens to be *M. pentafora* (doubtless *M. quinquefora* Lamk). But the form of the spines and spicules of my specimens, as well as the sculpture of the pits, does not agree with *M. quinquefora*, but very closely with *M. testudinata*. On the other hand, in the regularity of the arrangement of the pits on the surface, it differs materially from the photograph given in the Cambr. Mus. Cat. (No. 7, Pl. XII^c), of *M. testudinata*. Pl. III, Fig. 12, fragments showing surface sculpture, spines, and spicule.

Cellepora sp., (1). Pl. III, No. 1; A, lower, B, upper surface; fragments only found.

Cellepora sp., (2). Pl. III, No. 2; A, complete specimen, lower surface; B, upper surface; C, same magnified.

Pl. III.



A. KRUGER S.F. del. & sc.

APPENDIX X.

REPORTS UPON BRIDGING NAVIGABLE WATERS OF THE UNITED STATES.

X 1.

BRIDGE OVER THE OHIO RIVER AT BEAVER, PENNSYLVANIA.

OFFICE OF THE CHIEF OF ENGINEERS,
Washington, D. C., August 28, 1877.

SIR: I have the honor to submit herewith the report of a Board of Engineer officers, convened to take into consideration and report upon all matters relating to the location and plan of a bridge proposed to be built by the Pittsburgh and Lake Erie Railroad Company over the Ohio River, at Beaver, Pa.

The Board are decidedly of opinion that if the railroad company insist on a crossing below Phillipsburg they should increase the width of their channel-span.

The approach to the bridge from the left bank, as proposed by the railroad company, is through a tunnel 600 feet long and on a 7° curve. Such an approach to such a bridge appears to the Board to be very objectionable to the railroad itself, and, inasmuch as the river men whom they have consulted are almost unanimous in desiring that the bridge should be built farther upstream, they would recommend that this be done, and that a site between 300 and 400 feet higher up be chosen; giving the company a margin of 100 feet in order to adapt their line to the ground in a manner as advantageous as possible. But even with this change the channel space will often be difficult to run, as tows, after flanking around the Phillipsburg Point, cannot always straighten up in time to run straight through the channel space. For these reasons the Board would recommend that the channel space be increased to 425 feet in the clear, and that a smooth guiding-dike, 300 feet long, be built upstream from the left channel-pier. This dike should be as high as the 15-foot stage in the river, and should bend gently toward the bank so as to reduce the space for water behind it, and to deflect the current into the channel space. The left channel-pier should be placed 150 feet from the bluff bank.

Should the railroad company object to building this guide-dike, the Board would recommend that they be required to increase the clear opening at low water to 450 feet.

Should the company insist upon the location that they have already selected, the Board would recommend that they be authorized to build there, provided they will give a clear opening of 500 feet at low-water, or an opening of 450 feet with a guide-dike 500 feet long, and similar in other respects to the one described for the upper site.

Lastly, the Board would recommend that the company be authorized to build a bridge with 400 feet clear opening and no guide-dike, if they will locate it in the straight river above Phillipsburg.

Whichever of the sites indicated above be adopted, it is an essential condition that the piers shall be parallel to the current; the axis of the bridge may, however, vary a few degrees from being at right angles to the current if more convenient to the railroad company, provided the full width at right angles between the piers in the different projects be not reduced. This can be done by making the bridge-seats slightly oblique to the axes of the piers, and slightly lengthening the span, as is the case with the Bellaire Bridge.

The drawings of the proposed bridge show that all the openings are to be covered by deck-bridges, except the channel space, for which a through bridge has been designed. The Board would recommend that, whatever location be finally adopted, the span next north of the channel span be also made a through bridge. This change will give a side passage for single boats or for ascending tows of empty barges when the channel space is filled with descending tows. It is a very necessary change, as during short rises coal-tows pour out of Pittsburgh in a continuous stream with barely interval enough to prevent running into each other. An ascending fleet of empty barges might be detained a day from this cause only, and even single steamboats would be embarrassed if there were no side span through which to pass.

Finally the Board would recommend that, after the railroad company have made their election from the various methods of crossing herein recommended, their plans be inspected by the officer in charge of the improvement of the Ohio River to see that they are in conformity with the orders of the Secretary of War, and that they be submitted to the Secretary of War for his approval.

The Chief of Engineers concurs fully in the conclusions and recommendations of the Board.

By direction of Brigadier-General Humphreys and in his absence.

Very respectfully, your obedient servant,

GEORGE H. ELLIOT,
Major of Engineers.

Hon. GEO. W. MCCRARY,
Secretary of War.

[Indorsement.]

Approved.

GEO. W. MCCRARY,
Secretary of War.

WAR DEPARTMENT, *August* 30, 1877.

REPORT OF BOARD OF ENGINEERS.

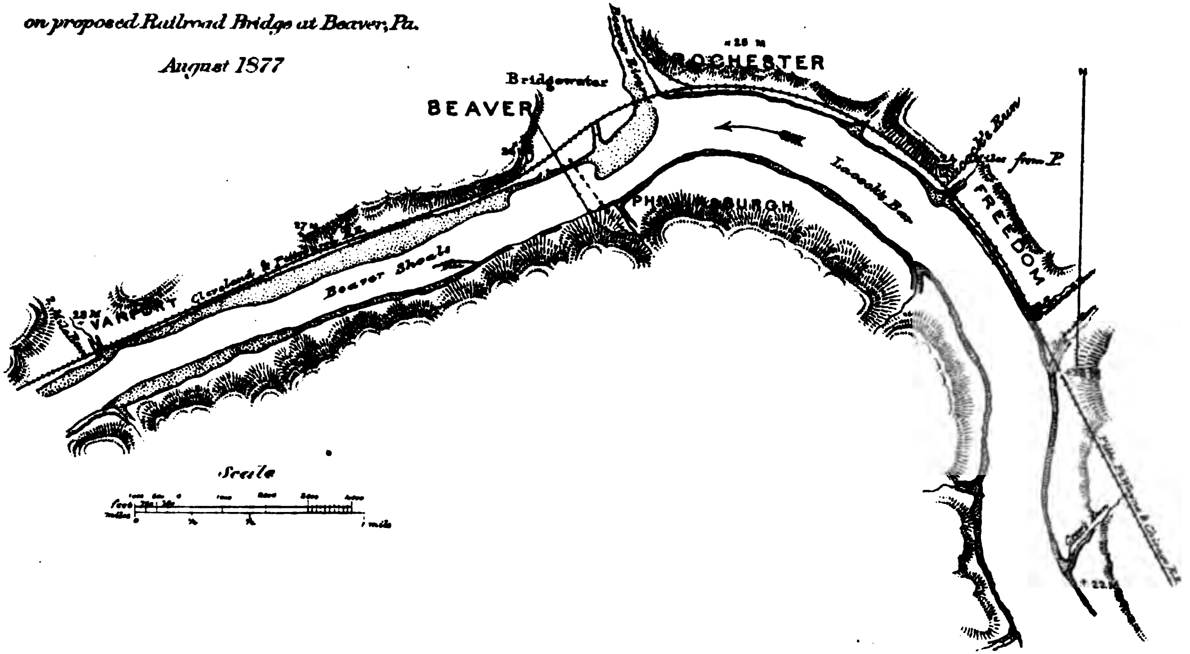
ENGINEER OFFICE UNITED STATES ARMY,
Saint Louis, Mo., August 15, 1877.

GENERAL: The Board of Engineers convened by Special Orders No. 88, Headquarters Corps of Engineers, August 1, 1877, "to consider and report upon the project for a bridge across the Ohio River at Beaver, Pa.," would respectfully submit the following report:

The special instructions of the Board which are contained in the letter of the Chief of Engineers dated August 1, 1877, state that the Board "will take into consideration and make an early report upon all matters relating to the location and plan of a bridge proposed to be built by the Pittsburgh and Lake Erie Railroad Company over the Ohio River at Beaver, Pa."

OHIO RIVER
at
Mouth of Beaver River.

To accompany Report of Board of Engineers
on proposed Railroad Bridge at Beaver, Pa.
August 1877



The Board met at Pittsburgh in obedience to the above orders, and made a careful personal examination of the site of the proposed bridge, in company with representatives of the railroad and the river interests. They also had many interviews with the officers of the railroad, and with the leading members of the Coal Exchange, which body is specially interested in endeavoring to protect their heavy shipping interests on the Ohio from unnecessary damage by bridges. The Board, therefore, believe that they are fully informed as to the views and wishes of all parties concerned in the erection of the bridge in question.

The present law governing the construction of bridges over the Ohio River was approved December 17, 1872, and may be found in the statutes of the United States for that year. The portions of this law that prescribe the location, dimensions, and method of construction of bridges at or near the locality in question are as follows:

SEC. 2. That every bridge hereafter erected across the Ohio River, above the mouth of the Big Sandy, shall have at least one span of a height of not less than ninety feet above low-water, and of not less than forty feet above local highest water, measured to the bottom chord of the bridge; * * * that this high span shall give a clear opening of at least four hundred feet between the piers, measured at right angles to the current at every stage, and that it shall be placed over the main channel of the river used by boats during ordinary stages of water. * * *

SEC. 3. That the piers of the high span * * * shall be built parallel with the current at that stage of the river which is most important for navigation, and that no ripraps or other outside protection for imperfect foundation will be permitted in the channel-way of the high span. * * *

SEC. 4. * * * ; and if the Secretary of war is satisfied that the provisions of the law have been complied with in regard to location, the building of the piers may be at once commenced; but if it shall appear that the conditions prescribed by this act cannot be complied with at the location where it is desired to construct the bridge, the Secretary of War shall, after considering any remonstrances filed against the building of said bridge, and furnishing copies of such remonstrances to the Board of Engineers provided for in this act, detail a Board, composed of three experienced officers of the Corps of Engineers, to examine the case, and may, on their recommendation, authorize such modifications in the requirements of this act as to location and piers as will permit the construction of the bridge; not, however, diminishing the width of the spans contemplated by this act: *Provided*, That the free navigation of the river be not materially injured thereby.

The site proposed by the bridge company is just below the town of Phillipsburg, opposite the mouth of the Beaver River, and 26 miles below Pittsburgh. Owing to the peculiar conformation of the hills on the left bank the railroad company is restricted in the choice of a bridge site within very narrow limits. It cannot cross between Phillipsburg and the little run that enters the Ohio just below the town, on account of the great cost of approaches on the left bank, and the fact that the approach from the right bank would be over the wide flat bar at the mouth of the Beaver. It cannot cross much below the mouth of the little run on account of the steep hill rising abruptly from the river, which even at the site chosen by the railroad company (600 feet below this run) has to be pierced by a tunnel on a sharp curve. It would be impossible to continue the line down the river along the side of the hill, as it is so abrupt as to leave no room for a curve in order to get on to a bridge.

These natural features restrict the choice of the railroad company for their southern abutment to a distance of about 700 feet, measured down the river from the mouth of the Phillipsburg Run. A crossing above Phillipsburg would be advantageous to the river interests, but the objective point of the railroad being the west bank of the Beaver River, such a bridge over the Ohio at this point would necessitate a second bridge over the Beaver, as the eastern bank of this stream is already occupied by the Pittsburgh and Fort Wayne Railroad. The great cost of this line would probably force the company to abandon their project, if it were selected. We may, therefore, conclude that the company is practically limited in choice to the 700 feet below the Phillipsburg Run.

Unfortunately, all of these sites are objectionable to the river interests for the following reasons: The currents in the Ohio opposite and below the mouth of the Beaver are variable. The map shows that at this point the Ohio makes a change of 90° in direction; that the Beaver River enters at the apex of the curve, and that there is a very large bar at the mouth of the latter, forcing the low-water channel of the Ohio over to the left shore. The high-water currents are also forced over to the same shore when high water in the Beaver is simultaneous with high water in the Ohio. But, on the other hand, a rise in the Ohio may be entirely a head rise, and the Beaver may be dead low, or nearly so. Under such circumstances the Ohio River currents are free to conform to the shape of the river, and if the rise is high enough to destroy the influence of the Beaver Bar the draught of water will be toward the middle of the river or to its right bank.

It is this variableness of current, combined with the natural difficulties of navigating the Beaver Shoals that begin just below the proposed bridge site, that makes the location a very undesirable one for navigation; in fact, we deem the site inadvisable, unless the bridge company will make up for its defects by an increase of span over the length prescribed by law.

The only site in this vicinity where a crossing with no increase in width of span should be permitted is above Phillipsburg, in the straight stretch of river that precedes the Beaver Bend. The objections to this site on the part of the railroad have already been stated.

The Board are, therefore, decidedly of opinion that if the railroad company insist on a crossing below Phillipsburg they should increase the width of their channel-span.

The approach to the bridge from the left bank, as proposed by the railroad company, is through a tunnel 600 feet long and on a 7° curve. Such an approach to such a bridge appears to the Board to be very objectionable to the railroad itself, and inasmuch as the river-men, whom they have consulted, are almost unanimous in desiring that the bridge should be built farther up-stream, they would recommend that this be done, and that a site between 300 and 400 feet higher up be chosen, giving the company a margin of 100 feet in order to adapt their line to the ground in a manner as advantageous as possible. But even with this change the channel-space will often be difficult to run, as tows, after flanking around the Phillipsburg Point, cannot always straighten up in time to run straight through the channel-space. For these reasons the Board would recommend that the channel-space be increased to 425 feet in the clear, and that a smooth guiding-dike, 300 feet long, be built upstream from the left channel-pier. This dike should be as high as the 15-foot stage in the river, and should bend gently toward the bank, so as to reduce the space for water behind it, and to deflect the current into the channel-space. The left channel-pier should be placed 150 feet from the bluff-bank.

Should the railroad company object to building this guide-dike, the Board would recommend that they be required to increase the clear opening at low water to 450 feet.

Should the company insist upon the location that they have already selected, the Board would recommend that they be authorized to build there, provided they will give a clear opening of 500 feet at low water, or an opening of 450 feet with a guide-dike 500 feet long and similar in other respects to the one described for the upper site.

Lastly, the Board would recommend that the company be authorized to build a bridge with 400 feet clear opening, and no guide-dike, if they will locate it in the straight river above Phillipsburg.

Whichever of the sites indicated above be adopted, it is an essential condition that the piers shall be parallel to the current; the axis of the bridge may, however, vary a few degrees from being at right angles to the current if more convenient to the railroad company, provided the full width at right angles between piers in the different projects be not reduced. This can be done by making the bridge-seats slightly oblique to the axes of the piers, and slightly lengthening the span, as is the case with the Bellaire bridge.

The drawings of the proposed bridge show that all the openings are to be covered by deck-bridges except the channel-space, for which a through-bridge has been designed.

The Board would recommend that, whatever location be finally adopted, the span next north of the channel-span be also made a through-bridge. This change will give a side passage for single boats, or for ascending tows of empty barges when the channel-space is filled with descending tows. It is a very necessary change, as during short rises coal-tows pour out of Pittsburgh in a continuous stream with barely interval enough to prevent running into each other. An ascending fleet of empty barges might be detained a day from this cause only, and even single steamboats would be embarrassed if there were no side span through which to pass.

Finally, the Board would recommend that, after the railroad company have made their election from the various methods of crossing herein recommended, their plans be inspected by the officer in charge of the improvement of the Ohio River, to see that they are in conformity with the orders of the Secretary of War and that they be submitted to the Secretary of War for his approval.

The Board herewith return the advertisements of the railroad company, as also their map, to which has been added, in dotted red lines, a new location, about 350 feet above the one originally indicated. The location in the straight river above Phillipsburg has not been indicated, as there seemed no probability that the company would choose it. They also inclose a map on the scale of 2 inches to the mile showing the general course of the Ohio for 3 miles above and the same distance below the mouth of the Beaver.

Respectfully submitted.

J. H. SIMPSON,
Col. of Engineers and Bvt. Brig. Gen., U. S. A., President of Board.
G. WEITZEL,
Major of Engineers and Bvt. Maj. Gen. U. S. A.
WM. E. MERRILL,
Major of Engineers and Bvt. Colonel.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

LETTER OF INSTRUCTIONS TO THE OFFICER IN CHARGE OF IMPROVEMENT OF THE OHIO RIVER.

OFFICE OF THE CHIEF OF ENGINEERS,
Washington, D. C., September 22, 1877.

SIR: The map presented to you for inspection by the engineer of the Pittsburgh and Lake Erie Railroad Company, showing the plan and location of the bridge proposed to be erected by that company over the Ohio River at or near Beaver, Pa., modified to conform to the recommendations of the Board of Engineers and of the Chief of Engineers, transmitted with your letters of the 12th instant, was duly received.

The map, together with your letters and your telegram of the 17th instant, in relation to the subject, was submitted to the Secretary of War, with the following indorsement, which has been been approved by him.

OFFICE OF CHIEF OF ENGINEERS,
September 19, 1877.

Respectfully submitted to the honorable the Secretary of War.

The map exhibiting plan and location of the bridge proposed to be erected over the Ohio River at Beaver, Pa., by the Pittsburgh and Lake Erie Railroad Company, modified so as to conform to the recommendations of the Board of Engineers, was submitted by the engineer of that company for inspection to Maj. William E. Merrill, Corps of Engineers, the officer in charge of the improvement of the Ohio River, who has forwarded it to this office.

It will be seen that Major Merrill reports that the map presented to him for inspection has been examined, and conforms to the views of the Board of Engineers constituted to report upon the plan and location of the bridge in question, and to the recommendations of the Chief of Engineers, which were approved by the Secretary of War. I have, therefore, to recommend that the modified plan and location, as shown on the map herewith submitted, be approved.

A. A. HUMPHREYS,
Brig. Gen. and Chief of Engineers.

You will please exercise such supervision over the bridge during its construction as will enable you to determine whether the views of the Chief of Engineers, as approved by the Secretary of War, are carried out by the company.

A tracing of the map will be sent for your information as soon as it can be prepared.

By command of Brigadier-General Humphreys.

Very respectfully, your obedient servant,

JOHN G. PARKE,
Major of Engineers.

Major WILLIAM E. MERRILL,
Corps of Engineers.

X 2.

BRIDGE OVER THE MISSOURI RIVER AT GLASGOW.

WASHINGTON, D. C., *April* 8, 1878.

SIR: "An act to authorize the construction of a bridge across the Missouri River at or near Glasgow, Missouri" (Public No. 22), having been passed by the Congress of the United States, and "approved March 13, 1878," and the construction of said bridge having been undertaken by the Kansas City, Saint Louis and Chicago Railroad Company, a corporation existing under the laws of the State of Missouri, and having been appointed chief engineer for the construction of said bridge, and authorized to act for the above-named company, as set forth in the letter of its president herewith inclosed, I have the honor to submit for your "examination and approval" the accompanying design and drawings of the proposed bridge, together with a map of the location, in compliance with the act, and intended to furnish the information required.

Very respectfully, your most obedient servant,

WM. SOOY SMITH,
Chief Engineer Glasgow Bridge.

The Hon. SECRETARY OF WAR.

[First indorsement.]

WAR DEPARTMENT, *April* 8, 1878.

Respectfully referred to the Chief of Engineers for report.

GEO. W. MCCRARY,
Secretary of War.

[Second indorsement.]

OFFICE OF CHIEF OF ENGINEERS, *April* 23, 1878.

Respectfully returned to the honorable the Secretary of War, inviting attention to the accompanying report of the Board of Engineers constituted for the purpose of examining and reporting upon the plans submitted by the engineer of the proposed bridge at Glasgow.

It will be seen that the Board is "of the opinion that if the bridge be located and constructed as delineated upon the map and drawings submitted to them, the law will be complied with and the safety and convenience of navigation unimpaired."

I concur in the views of the Board, and beg leave to recommend that the location and plan of the bridge as set forth in the accompanying drawings, &c., be approved.

A. A. HUMPHREYS,
Brig. Gen. and Chief of Engineers.

[Third indorsement.]

Approved.

GEO. W. MCCRARY,
Secretary of War.

APRIL 29, 1878.

REPORT OF BOARD OF ENGINEERS.

ENGINEER OFFICE, UNITED STATES ARMY,
Saint Louis, Mo., April 17, 1878.

GENERAL: The Board of Engineers convened by Special Orders No. 40, Headquarters Corps of Engineers, Washington, D. C., April 9, 1878, to consider and report upon the plan and location of the bridge proposed to be erected over the Missouri River in accordance with the provisions of "An act to authorize the construction of a bridge across the Missouri River at or near Glasgow, Missouri," approved March 13, 1878, have the honor to submit the following report:

The Board met at Saint Louis on the 15th, and proceeded to consider the following documents and drawings laid before them by the presiding officer:

1st. Letter of instructions from the Chief of Engineers to the president of the Board, dated April 9, 1878, inclosing letter from William Sooy Smith, chief engineer of the Glasgow bridge, to the honorable Secretary of

War, dated Washington, D. C., April 8, 1878; also letter from John J. Mitchell, president Kansas City, Saint Louis and Chicago Railroad Company, to the honorable Secretary of War, dated Saint Louis, Missouri, April 1, 1878; also a copy of the act of Congress approved March 13, 1878, authorizing the construction of the bridge under consideration.

2d. Two sheets of drawings furnished by the chief engineer of the bridge, and based upon surveys made by him when the river at Glasgow was at a stage of 6 feet above low water mark, viz, one of them a map of the Missouri River in the vicinity of Glasgow, drawn to a scale of 300 feet to the inch, showing the site of the proposed bridge with location of piers and approaches thereto by water for 1 mile above and below the bridge, also showing the velocities and directions of river-currents as well as the land approaches to the bridge. The other drawing on a scale of 30 feet to the inch, containing plan and profile of the piers, superstructure, and approaches by land, the profile also showing the lines of high and low water, the bottom of river and position of bed-rock.

Mr. Smith appeared before the Board the next day (the 16th) for consultation, and made at the same time some corrections of the drawings necessary to a full understanding of the plan.

Glasgow is situated on high ground on the left bank of the Missouri, below what is known as Glasgow Bend. The course of the river toward the bluffs above the town is nearly northwest; thence, curving sharply to the right it finally pursues a direction past the town nearly due south. The apex of the curve of the bend is somewhat more than a mile above the bridge site, which is on the prolongation of Jackson street, giving the channel room to assume a straight and defined course along the city front. The Chariton River, a small stream, discharges into the bend about 1½ miles above the bridge site. The right bank of the river opposite to Glasgow is of alluvion, rising to a general height of 22 feet above low water mark and runs sensibly parallel in direction with the left bank until within about 700 feet above the bridge site, from which point the banks begin to diverge gradually with a corresponding increase in width of the stream. The bottom of the river is of light material, the bed-rock underlying it according to the profile at depths of from 5 feet close to the left bank to 30 feet at the edge of the opposite bank, below the surface of low water. The oscillation of the stream, or difference between high and low water, is about 21 feet as per profile. The velocity of current 5 feet below the water surface, as observed by Mr. Smith when the river was at a stage of 6 feet above low water, varies from about 3 feet per second to about 7½ feet per second, the latter being the observed velocity about midstream.

The bridge as proposed to be erected by the Kansas City, Saint Louis and Chicago Railroad Company is to be a high bridge, and to consist of 5 spans of 300 feet each in the clear between piers, measured on the line of lowest water; the piers in the main channel to be about 15 feet in width and about 46 feet in length, measuring from the apexes of the startings. The first, or shore pier, on the Glasgow side, to be located about 27 feet inside of the shore-line at the 6-foot stage of water. The superstructure of three of the spans, commencing on the Glasgow side, to be through spans, Whipple truss, the lowest part of the truss to be at a height of 50 feet above the surface of the river at highest water. The superstructure of the fourth and fifth spans, to be deck-spans of the same style of truss, rising on a slight grade from the right bank; the lowest part of truss No. 4 to be at a height of 10 feet above highest-water mark; truss No. 5, spanning the space between the right bank and pier

No. 5, to give close to the latter pier a clear space of 10 feet from its lowest part to highest-water surface, this vertical distance gradually diminishing to 8 feet at the edge of the bank, a difference of no practical importance, as but little water would flow through this (fifth) span at highest stages of the river.

By consulting the map it will be seen that the axis of the proposed bridge is sensibly at right angles to the general direction of the currents, and the piers sensibly parallel thereto. There being but five spans the piers will not be in sufficient number to present any material obstacle to the flow of water; in addition, the yielding nature of the bed will enable it to easily adjust itself to the new conditions of flow. Ample space is left for the high water discharge.

The approaches on the Glasgow side to consist mainly of an embankment, and those on the opposite side of trestle-work. The span adjoining the left bank presents the advantage of enabling boats to drop through it close to the shore during high water stage when increased velocity of current is to be apprehended. The right bank rising above the high water level, it is not thought that any material change in direction of the current from what it now is will obtain at high water. The location of the bridge is such that at highest stage of water three spans of 300 feet each will be fully available for the passage of boats, and at low water two of the high spans and part of a third, over the main part of the river, will be available.

The act approved March 13 requires in the case of construction of a high bridge—

> That if said bridge shall be made with unbroken and continuous spans, the spans thereof shall not be less than three hundred feet in length in the clear, and the main span shall be over the main channel of the river. The lowest part of the superstructure of said bridge shall be at least fifty feet above extreme high water mark as understood at the point of location, and the bridge shall be at right angles to, and its piers parallel with, the current of the river, &c.

The Board are, therefore, of the opinion that if the bridge be located and constructed as delineated upon the map and drawings submitted to them, the law will be complied with and the safety and convenience of navigation unimpaired.

The papers and drawings specified in your letter of the 9th are herewith respectfully returned.

All of which is respectfully submitted.

J. H. Simpson,
Col. of Engineers and Bvt. Brig. Gen., U. S. A., President of Board.
Chas. R. Suter,
Major of Engineers.
Chas. J. Allen,
Captain of Engineers.

Brig. Gen. A. A. Humphreys,
Chief of Engineers, U. S. A.

X 3.

REPORT OF BREVET MAJOR-GENERAL G. K. WARREN, MAJOR OF ENGINEERS, UPON BRIDGING THE MISSISSIPPI RIVER BETWEEN SAINT PAUL, MINNESOTA, AND SAINT LOUIS, MISSOURI.

WAR DEPARTMENT,
Washington City, April 25, 1878.

The Secretary of War has the honor to transmit to the United States Senate, for the Committee on Commerce, report of Bvt. Maj. Gen. G. K. Warren, Major of Engineers, upon the subject of bridging the Mississippi River. This report, together with the letter of the Chief of Engineers and accompanying maps, is submitted in compliance with section 4 of the river and harbor act, approved June 23, 1866.

The views and recommendations of General Warren are approved by this department.

In the absence and by direction of the Secretary of War.

H. T. CROSBY,
Chief Clerk.

LETTER OF THE CHIEF OF ENGINEERS.

OFFICE OF THE CHIEF OF ENGINEERS,
Washington, D. C., April 25, 1878.

SIR: I beg leave to submit herewith the accompanying copy of the report of Bvt. Maj. Gen. G. K. Warren, Major of Engineers, upon the subject of bridging the Mississippi River, as directed by the following clause of section 4 of the river and harbor act of June 23, 1866:

> For examining and reporting upon the subject of constructing railroad bridges across the Mississippi River, between Saint Paul, in Minnesota, and Saint Louis, in the State of Missouri, upon such plans of construction as will offer the least impediment to the navigation of the river.

The surveys and investigations in the field and the preparation of a map of the valley of the Mississippi were continued in the years 1867, 1868, and 1869, and partial reports thereon were rendered from time to time as were required in special cases.

Numerous other important duties were assigned to General Warren while making this investigation, the most noticeable of which was the design and partial construction of the bridge at Rock Island. Early in 1870 he was detailed to the charge of the United States Lake Survey, but about this time a serious illness making it necessary, his station was changed to Newport, R. I.

This report was further delayed from a press about this time for reports on special bridge projects, and in 1876 further surveys were found to be necessary on account of the additional bridges that had been built since the surveys of 1869.

For these reasons the preparation of this important report, in suitable form for publication, has only just been completed.

The object of this investigation was to devise a plan of bridging the Mississippi such "that while the railroads could be accommodated the navigation should be preserved," conditions which, adverse in themselves, could only be harmonized and made practicable by reasoning founded upon facts and the teachings of experience. Time was required to bring these conditions suitably together. They involve the most essential facts of observations upon currents at all stages; the record of the rise and fall of the river for a series of years, such as would give a useful mean result; the development of engineering capabilities of bridge-building which, under the stimulus of a greater demand, now accepts as accomplished facts railroad truss-spans of 500 feet, upon piers 100 feet above water, and other developments, such as that of water transportation by fleets of barges propelled and guided by steamboats. All these required the time that has been diligently employed in bringing this new knowledge to bear upon the question to be solved.

When the investigation was authorized in 1866, there was not a railroad bridge authorized by law of the United States upon the Mississippi between Saint Paul and Saint Louis, although one, very obstructive to navigation, had been erected at Rock Island, and another, not quite so much so, at Clinton. At present there are eleven railroad draw-bridges in the same part of the river and several others authorized but not yet built. Probably others will still be desired.

Under the provisions of existing laws, reserving to the United States the right to require an alteration of these bridges when the interests of navigation make it requisite, it is indispensably necessary to have this accurate data at hand that justice may be done in the interest of all parties and the public. This report should, therefore, be published, together with its numerous illustrative diagrams, which can be reproduced by the inexpensive photolithographic process, as the engineering questions cannot be properly considered without them.

These surveys have, together with those previously made, furnished data of much value for the use of the Board of Engineers upon the construction of sheer-booms for the security of the navigation of the Mississippi River.

Accompanying the report is a general map of the valley of that part of the great river required for the consideration of the subject, which is, in itself, a valuable contribution.

In transmitting this report I desire to express my full concurrence in the views and recommendations of General Warren.

Very respectfully, your obedient servant,

A. A. Humphreys,
Brigadier-General and Chief of Engineers.

Hon. Geo. W. McCrary,
Secretary of War.

LETTER OF TRANSMITTAL.

Engineer Office, United States Army,
Newport, R. I., March 7, 1878.

General: I have the honor to present herewith my final report upon the investigation of the question of bridging the Mississippi in such manner as to preserve the navigation, assigned to me under section 4 of the act for the improvement of rivers and harbors, &c., approved June 23, 1866.

Very respectfully,

G. K. Warren,
Major of Engineers and Brt. Maj. Gen., U. S. A.

Brig. Gen. A. A. Humphreys,
Chief of Engineers, U. S. A.

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REPORT.

CHAPTER I.

PREFATORY.

Origin and nature of this investigation. References: To Chapter II, on the formation of the Mississippi Valley and depth to "*bed-rock*"; to Chapter III, a general presentation of Western river-navigation, with discussion of the question of "headway"; to Chapter IV, descriptions of the bridges on the Mississippi; to Chapter V, a history of bridging the navigable Western rivers; to Chapter VI, an account of surveys made, &c.—CONCLUSION RELATIVE TO THE PROPER KIND OF BRIDGE.

Origin and nature of this investigation.—This report was authorized by the following provisions contained in section 4 of the act making appropriations for rivers and harbors and other purposes, approved June 23, 1866:

> For examining and reporting upon the subject of constructing railroad bridges across the Mississippi River, between Saint Paul, in Minnesota, and Saint Louis, in Missouri, upon such plans as will offer the least impediment to the navigation of the river.

Instructions to me from the Chief of Engineers, United States Army, dated August 2, 1866, after assigning other duties to me, say, this "duty is also confided to you, and you will collect all the information pertaining to it."

This enactment in regard to bridging the Mississippi had its origin in a resolution introduced in the Senate (prior to the passage ot any act authorizing bridges upon the Mississippi River) by the Hon. Alexander Ramsey, chairman of the Committee on Post-Offices and Post-Roads, and I was instructed to confer with him on my arrival at Saint Paul as one who would furnish me "facilities for procuring much valuable information preliminary to my labors." By him I was furnished with a copy of the debates in Congress on this subject, and taking these as a guide to the nature and extent of the information I was to collect, I probably had a field of investigation more extended than usually falls to an engineer, but in no case have I gone beyond the matters collateral to, if not directly affecting, the strict engineering questions. I have made abstracts of these debates, and give them in Chapter V of this report.

It would be a simple matter to report that a bridge giving about 85 feet clear space above high water with spans of 500 or 600 feet (which, in an engineering point of view, are practicable) would offer no obstruction to navigation on the Upper Mississippi or elsewhere where vessels are propelled by steam and not by sails, and thus meet the requirement of the act; but it is evident from the debates that the "plans" which shall "offer the least impediment to navigation" must be based not merely upon questions of engineering capabilities. These plans must be within limits of practicability as to cost, and be adapted to the place where needed and to the service required of the bridge. The plans must therefore make reasonable provisions for all the requirements of the case, and the presentation must be accompanied by the facts and other evidences of practicability and utility. Such is my view of the duty confided to me, and it seems implied at least in the instructions to "collect all the information appertaining to it."

The passage of several acts authorizing bridges on the Upper Mississippi does not do away with the necessity of this investigation, because the right is reserved by Congress to make such additional legislation as the protection of the navigation may be found to require, and there are some bridges built that are not authorized by Congress which may come before it for consideration and action. Investigation is thus as important for the purposes it was ordered, at the present time, as it was at the outset.

The necessity of bridging the Mississippi was conceded by every one. The only question was as to the kind of bridge, whether to be low ones with draw openings or continuous and of height sufficient to allow vessels to pass under them. The high bridges were advocated by those interested in the navigation, and opposed by those more concerned in crossing the river, as being impracticable on account of cost. The low bottom-land banks of the Mississippi River and their great width, the opponents of high bridges said, make the high approaches too expensive. Besides this, the bed of the river was stated to be generally of sand to so great a depth that foundations could not be laid upon the underlying rock, the only secure manner of building such high piers. To furnish definite information on these points was evidently one of the objects of the investigation. The Hon. Alexander Ramsey, mover of the resolution, said, on April 30, 1866:

> Survey the whole river and decide, at least as to the future, what should be the character of the bridges there.

And in another place:

> To survey the river, and settle the essential points to be guarded in the construction of these bridges, how, where at the same time the railroads may be accommodated, and the navigation preserved.

The kind of survey intended could only be of a very general character, as only $10,000 was provided in the resolution for making it, and it is probably better described by another remark of the Senator:

> To send out to view the river and furnish us the best information on the subject.

It was at first intended that the report should be submitted at the next session of Congress, but the passage at the same session of the acts authorizing all the bridges whose construction had been urged allowed more time. In making it, advantage was taken of surveys of the Mississippi ordered for purposes of improving navigation, and thus a great deal more was done than this appropriation for the special purpose would have permitted.

The remainder of this chapter will be given to presenting the manner in which the report is made up and noting some of the most important deductions.

Formation of the valley of the Mississippi River and depth to bed-rock.— General considerations leading to a knowledge of the general depth of the bed-rock beneath the sand caused me to prepare a map on a scale of six miles to an inch, including the Minnesota River. The drainage of the great basin of Lake Winnipeg appears to have been formerly along this valley. The discussions and conclusions relating to this part of the subject form Chapter II of this report. There seems every reason to believe that the bed-rock can generally be reached for pier foundations by means of the pneumatic process, which has been abundantly employed during the period this investigation has been going on at Omaha, Saint Louis, Saint Joseph, and Saint Charles. At the end of the chapter is a table giving the areas of the drainage of all the tributaries to the valley above the mouth of the Ohio.

A general presentation of Western river navigation and a discussion of question of headway are given in Chapter III of this report.

The interests of navigation, as represented by the Saint Louis Chamber of Commerce, held that no bridge should be built that did not leave a clear headway over the main navigable channel of at least 50 feet at time of extreme high-water. There is reason to believe that the extreme high-water referred to was that of the highest known, and not of the ordinary high-water; for while it is true that during such very great floods business is generally suspended, yet by placing the bridge 50 feet above that level it gave an increased headway for all ordinary floods and for high stages approaching the level of ordinary floods.

There has been, so far as I know, no thorough discussion of the subject of relative headway at ordinary stages at different places on the Mississippi.

It is obvious enough that 50 feet above extreme high-water where the river range is 40 feet and where it is 20 feet is a difference of 10 feet in favor of the first place when the river is at a half stage; that is, there will be 70 feet headway at one place and 60 feet at the other at such time. A different provision in respect to height of, high bridges in general seems required.

The United States law authorizing the bridge at Saint Louis, however, provided for a headway of about 50 feet at ordinary high-water, which stage is about 7 feet lower than extreme high-water of 1844.

The discussion in Chapter III shows (if we provide on the river above Saint.Louis for only the ordinary high-water) that an elevation of about 57 feet above ordinary high-water will be required to give a headway equivalent to that at Saint Louis. This investigation seems to have established the practical rule for all rivers that equivalent headway at different places requires that the height of the bridges measured from the level half way between high and low water should be the same for all places. This is one of the most important contributions to the subject made by this investigation, and it was essential to reaching it that the observations should have extended over the considerable number of years which it has.

A table of rise of water from low to high stages on the Mississippi, Ohio, and Missouri Rivers is given at the end of this chapter.

Lengths of spans.—Experience in the interval of time which has elapsed since the investigation began has settled all questions with regard to the practicability of long spans. At Cincinnati there is a railway-bridge with a clear span of 500 feet over the channel of the Ohio. It is of the American pattern of horizontal truss, composed of wrought iron, resting upon piers 100 feet above low-water. There is also at Cincinnati a railway truss-bridge with one span of 400 feet. At several places there are railway bridges with spans between 300 and 400 feet, and many spans of railway bridges of 300 feet width in the clear.

At Louisiana, Mo., there is a railway pivot draw-bridge across the Mississippi of 200 feet clear openings, and propositions are now made by competent builders and engineers to employ two such pivot draw-bridges, and thus leave one clear opening of 400 feet and two others of 200 feet each side of it.

It must be admitted that engineers can make ample provisions for navigation. Accomplished facts leave this no longer a question.

Description in detail of the bridges on the Mississippi from Saint Paul to Saint Louis is given in regular order, descending the river, n Chapter IV, which concludes with a list of bridges authorized but not built.

In Chapter V is given a general history of bridging the navigable Western rivers, in its relation to the laws; to the decisions of the United States courts; to the debates in Congress; to the opinions of engineers, &c., arranged in nearly a chronological order. This will be found useful to those having to consider this question in any of these relations. At the end of this chapter is an abstract of the United States laws relative to bridges on the Mississippi, Ohio, and Missouri Rivers. Special attention is asked to the defenseless condition of the navigators before the United States courts, under existing laws, as shown by this history. When the first Rock Island bridge was built the injuries to navigation which followed caused suits of various kinds to be at once brought against it, and an appeal was also made to Congress. A committee appointed by the House of Representatives reported that the courts afforded ample protection. After several years of suffering the navigation interest obtained a decree from the United States district court of Iowa decreeing the removal of part of the bridge. On appeal the United States Supreme Court set this decree aside because of want of jurisdiction in the district court. When the laws were framed in 1866 authorizing bridges, a special section was adopted, giving jurisdiction to the district courts. But another section in the laws, making the bridges post-routes, gives absolute protection to the bridges and none to the boats. There have been no suits brought by steamboat-owners against the bridges so authorized. They have to bear the injuries to the vessels, and are liable to suits for the injuries their cargoes sustain and for any damage to the bridge. Something should be done about this.

This report is limited to presenting the Western river navigation and bridges by themselves. From having been a member of boards to consider the question of bridging the navigable channels between the great lakes, I am equally well acquainted with them, but as the vessels there use sails as well as steam, and are otherwise entirely different in construction and management, the principles applicable to one of these navigable waters are inapplicable to the others. The same remark is true of the bridges over estuaries of the Atlantic seaboard.

In Chapter VI is given an account of the surveys and circumstances under which the maps and report have been prepared, with lists and descriptions of all the maps made and the manner of constructing them; also lists of maps obtained from others, and an account of the way in which all have been used in compilation.

CONCLUSION RELATIVE TO THE PROPER KIND OF BRIDGE.

Among a number in Congress in 1866 who yielded to the necessity for passing the act authorizing the construction of the railway draw-bridge at Quincy, Ill., it was felt that, although such a bridge was a serious obstruction to navigation, it might be borne if the number of such bridges was small, but that if the number was increased to a dozen their combined obstruction would become insupportable. Not counting draw-bridges authorized but not built, those now in existence have more than reached the limits of aggregate obstruction to navigation that can be borne without suffering great loss. Such bridges "accommodate" the railroads, but the delays they occasion to vessels at nights and during winds, which do not interfere with the navigation of other parts of the river, prevent all regularity in the running of steamboats, and destroy the systematic arrangements for loading and unloading freights, upon which economical and profitable management depends.

On the contrary, moderately high bridges, allowing the proper headway under them for the passage of pilot-houses of necessary elevation (which, while occasioning some expense and inconvenience in adopting suitable chimneys, when once done, is done for all), can be increased in numbers independently, without materially increasing the obstruction to navigation. Experience has shown that it is practicable to build these high bridges with any needed width of clear spans.

Cheap transportation, the great want of the Mississippi Basin, can only be secured by the barge system, requiring wide openings between the piers, which low draw-bridges, such as now constructed, cannot give. Wider openings may be secured by double pivot draw-openings, but as a practical matter it remains to be established.

The conclusion then (which the whole of this investigation and report sustains) is, that high bridges with wide spans are the only kind that will with certainty "accommodate the railroads, and at the same time preserve the navigation."

CHAPTER II.

VALLEY OF THE MINNESOTA RIVER AND OF THE MISSISSIPPI RIVER TO THE JUNCTION OF THE OHIO—ITS ORIGIN CONSIDERED—DEPTH OF THE BED-ROCK.

Definition of the term *valley*—Prominent natural features and length—General maps prepared for publication—Method of considering questions of depth of bed-rock—Explanation of the cause of Lake Pepin and similar lakes—Valley now filling up—Recent drainage of Lake Winnipeg southward—Valley formed since the glaciers began to retire—How the valley was formed—Anomalies of Rock Island Rapids and Des Moines Rapids—Loess formation—Formation of rapids since the Loess—Summary of principal points presented—Explanatory hypotheses—Approximate practical conclusion—Sections of best known parts of valley in regard to depth of bed-rock—Contour map of the sources of the Mississippi—Table of areas of basins drained by the tributaries to the valley.

Definition of the term "valley," prominent natural features and length.—The *valley* to be considered is the part included between the high banks, commonly called bluffs. Whenever it becomes necessary in this report to refer to the whole area drained by the river, the word *basin* will be used to designate it.

Between these high banks the greater portion is subject to overflow at time of floods, forming what is sometimes called the *flood plain;* the smaller part above overflow is generally composed of alluvial terraces of sand and gravel. In some cases the distinction between the terraces and the bluffs is difficult to make.

The Mississippi River in its usually navigated parts touches only here and there at places exempt from flood-waters, and these are natural landings for steamboats and sites for towns. In course of time the convenience of the people living there makes them desirable locations for bridges. It is very rare, however, that both banks of the river are above submergence; where one bank is, the opposite one is generally low, and covered many feet deep at extreme high-water, making it difficult to construct bridges sufficiently elevated for steamboats to pass under them.

The distance along the general course of this valley from Saint Louis to Saint Paul is about 620 miles, but steamboatmen, by the course they take along the navigable channels, make the distance about 800 miles. This was the only part specified in the law authorizing this investigation, but it was necessary in order to present the subject itself properly to include the whole distance from the mouth of the Minnesota to the Ohio; this is an extent of about 760 miles along the general course of the valley, and we have prepared a map of it in twenty-two sheets on a scale of two inches to a mile. The manner in which this has been done is described in Chapter VI of this report.

General map and profile prepared for publication.—Although we have, in constructing the map, exhausted all means of obtaining knowledge in regard to this part of the Mississippi Valley, there are some parts of it too little determined to make its publication, as a whole, advisable, and therefore we have only prepared for publication the index map of those twenty-two sheets, on a scale of six miles to an inch. (If photographed it may vary from this scale.) Here, again, generalizations have led us to make this index map include the Minnesota River Valley.

That valley, under another clause of the law, was also made a part of my investigation, and a map in twenty sheets on a scale of two inches to the mile was made for it. The map submitted for publication is also an index map to those Minnesota Valley sheets now on file at Engineer headquarters in Washington. We have also extended this general map southward so as to include overflowed land as far as the northern part of Arkansas, and northward to include a part of the basin of the Red River of the North. It is designated as Diagram 1, in five sheets.

The two systems of United States land surveys (one on each side of the Mississippi River) are so checked upon each other in its construction and by special surveys by ourselves, that the valley on this small scale is probably as correct as it can be represented. The whole of the flood-plain is shaded with light-ruled lines, except the principal lakes and water-courses, which are shaded with heavy-ruled lines. The alluvial terraces above overflow are shaded with dots. The high banks or bluffs are without shading. On sheet five there are some overflowed lands that are above the Mississippi floods, which have special shading.

In order to complete a presentation of the Mississippi flood-plain to the Gulf of Mexico, the page Diagram A is added, reduced from Plate II of the report of Humphreys and Abbot on the physics and hydraulics of the Mississippi.

General considerations as to the formation of the Mississippi Valley have caused me to present also the page Diagram B, showing the Mississippi basin as it is, and extending northward to include the Lake Winnipeg basin with the ancient extension of the lake southward and outflow through the valley of the Minnesota and Mississippi Rivers.

Profiles prepared for publication.—Accompanying this chapter are two sheets of longitudinal profiles of the valley from the junction of the Minnesota River to the junction of the Ohio. The horizontal scale is about 8 miles to an inch, and the vertical 200 feet to an inch (reduced in publication). The datum is the sea-level according to the best determinations, and both sides of the valley are given side by side. The parts of the banks above low-water are shaded to indicate the strata of different geological periods, but it must be borne in mind that this low-water line does not represent the low-water slope of the winding river, but is drawn from point to point along the general course of the valley, so as to bring the rocks into their proper relative positions. These longitudinal profiles are designated as Diagram 2, in two sheets.

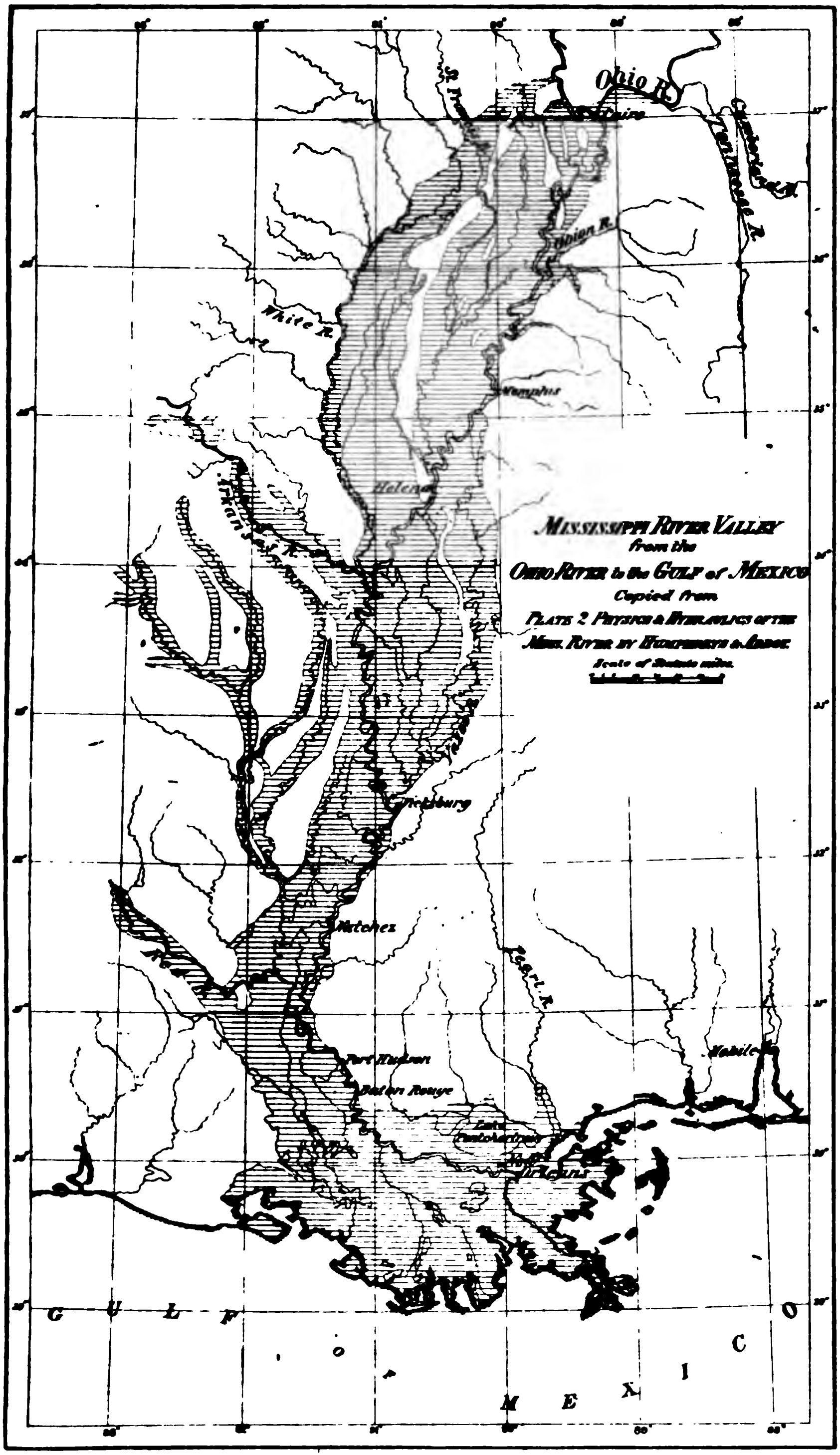
Another sheet, designated as Diagram 3, gives 20 transverse valley sections, on a larger scale than the profiles—three of them on the Minnesota Valley; one on the Mississippi, above the junction with the Minnesota; fourteen of them in the valley between the Minnesota and the Ohio; one at the mouth of the Missouri River, and one at the mouth of the Illinois River. These sections are designed to show the extent of our positive knowledge of the depth of the bed-rock, and will be described in detail in the latter part of this chapter.

We are mainly indebted for the geological data in these profiles and sections to the report of David Dale Owen, of October, 1851, on the geological survey of Wisconsin, Iowa, and Minnesota; to the report on the geological survey of Iowa, by Prof. James Hall, J. D. Whiting, and Mr. A. H. Worthern, published in 1858, and the report of Mr. A. H. Worthen, director of the geological survey of Illinois, published in 1866.

Method of treating question of depth of bed-rock.—The question of depth of the bed-rock beneath the sand that usually forms the bed of the river will occupy the remainder of this chapter.

In presenting my ideas in regard to it, I have thought the best order in which I could arrange them would be that in which they arose in the

Warren's Rep't. Bridging Mississippi River. *Diagram A.*



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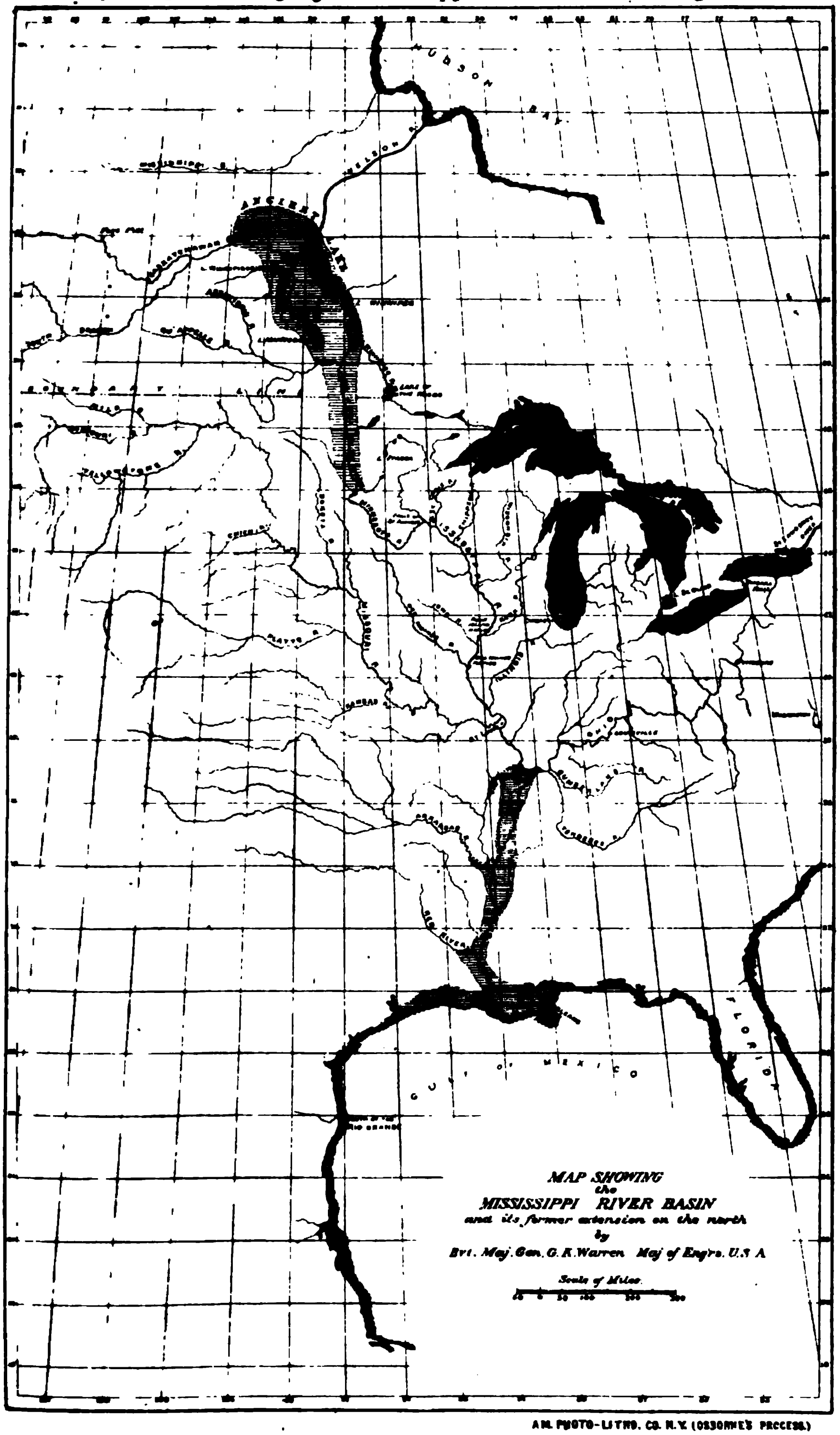
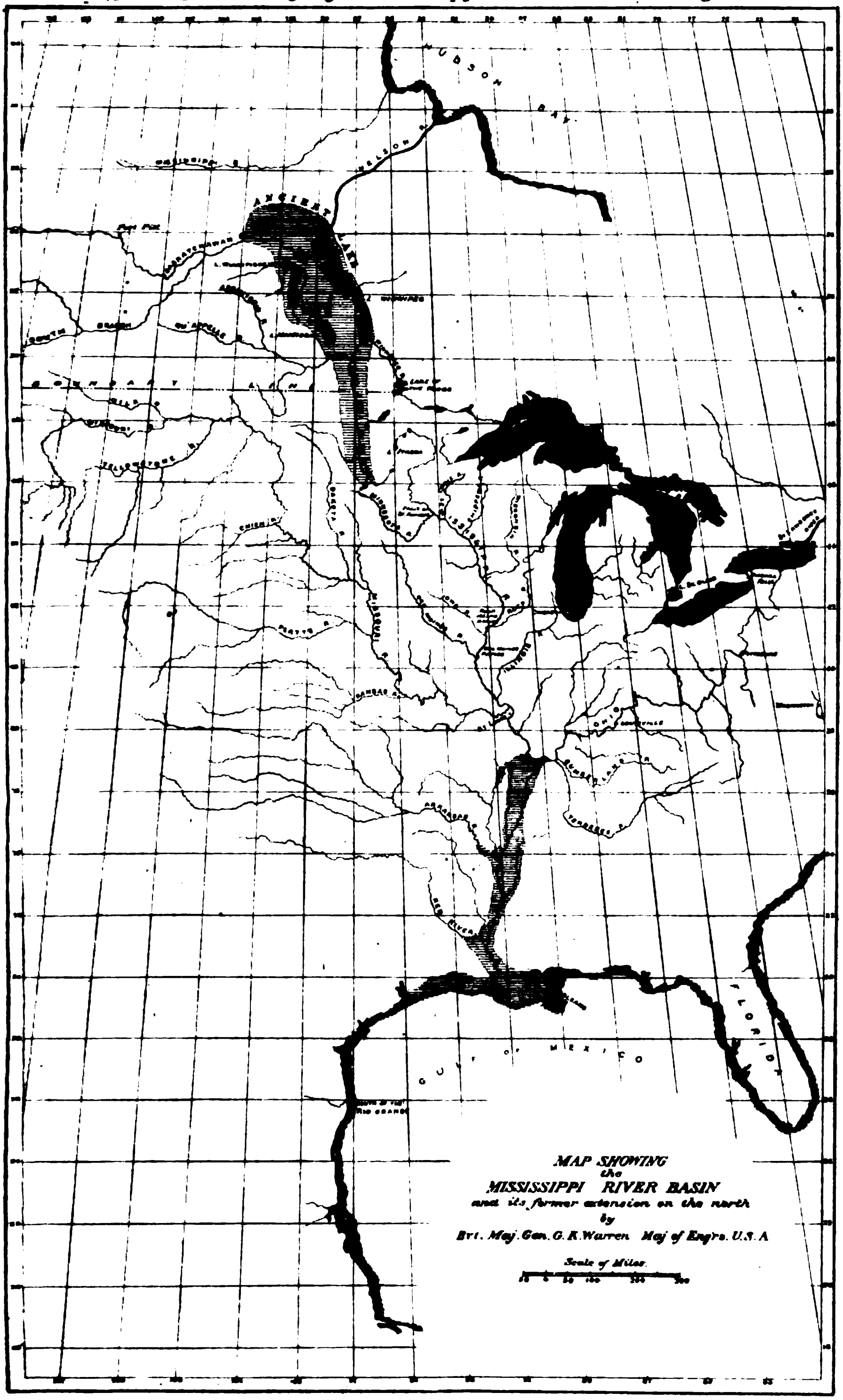


MAP SHOWING
the
MISSISSIPPI RIVER BASIN
and its former extension on the north
by
Bvt. Maj. Gen. G. K. Warren Maj. of Engrs. U.S.A.

AM. PHOTO-LITHO. CO. N.Y. (OSBORNE'S PROCESS.)

Warren's Report. Bridging Mississippi River. *Diagram B.*



MAP SHOWING
the
MISSISSIPPI RIVER BASIN
and its former extension on the north
by
Brt. Maj. Gen. G. K. Warren Maj of Engrs. U.S.A

Scale of Miles.
50 0 50 100 200 300

AM. PHOTO-LITHO. CO. N.Y. (OSBORNE'S PROCESS.)

progress of the investigation. It was from the first obvious that means and time would not allow of my covering such an extended field by actual borings, and that the most that could be done was to draw such probable inferences as could be done by a study of the rocks visible in the bluffs and by an effort to comprehend the manner in which the valley was formed.

The consideration of the anomaly presented by Lake Pepin lying in the course of the river, and said to have a depth of 60 feet near its lower end, was the beginning of this effort. If the valley in this portion had once been all of this depth, and since filled in, then the bed-rock could not be less than 60 feet below the water surface. Explanations of the cause of this lake had been attempted by Long and by Featherstonhaugh, which did not seem to me satisfactory.

Explanation of the cause of Lake Pepin and similar lakes.—The results of the levelings on the Minnesota and Mississippi rivers made by me showed that just below the entrance of any considerable affluent there was an accumulation of deposit in the main stream brought by the tributary; that over this deposit the slope of the water was greater than the average slope, and that it was shoal and impeded navigation; that just above the affluent the slope was less than the average, and the water deeper. So far, this was in accordance with conditions which generally exist in rivers, and might be so even where the main stream was gradually wearing away and deepening its bed.

But a marked peculiarity was exhibited at the junction of the Minnesota and Mississippi rivers. Regarding the Mississippi as the affluent (which we might do from the comparative sizes of the two valleys), the rule here would be as it is elsewhere, steep slope and shoal water below the affluent and almost no slope and very deep water above. In this instance the effect is felt above for at least 30 miles. On the other hand, taking the Mississippi as the main stream (as the volume of its water has always caused it to be regarded), then we have the anomaly of the main stream filling up the valley and damming back the affluent, so that the latter brings no coarse material whatever into the main valley or has any part in forming the shoal below the junction of the two streams.

I called attention to this in my report published in 1867, and again made the anomalous condition a feature in my report on the Minnesota River (An. Rep. Chief of Engineers, 1875, Part I, page 387), where a diagram was given of the streams and valleys at the junction, which I here report as Diagram C. In that report I showed that the valley of the Minnesota River had in the period subsequent to the glacial-drift epoch been occupied by a much larger river, which had formed the outlet of a great lake, embracing the lake Winnipeg and receiving the drainage of its basin, and extending as far south as the present *Lac Travers* at the source of the Minnesota River. This ancient river, if its volume were as great in proportion to area as that of the Mississippi above the Falls of Saint Anthony, probably equaled Niagara in volume, and would have been sufficient to prevent the formation of such excessive accumulation of *débris* in its course, such as the Mississippi is now making below the junction of the Minnesota River, although it is probable that the material brought into it from the near proximity of the Falls of Saint Anthony would have had the usual effect of somewhat increasing the slope and shoalness just below its junction, and decreasing the slope and increasing the average depth just above.

Accepting, then, the conclusion which I have elsewhere made reasonable, that the drainage of the Winnipeg basin was formerly along the Minnesota and Mississippi below the junction, then when the flow of water from that great northern basin ceased there would no longer be the volume of water necessary to remove the deposits brought by the affluents into a channel of too great capacity for the requirements of the new conditions.

In building the railroad bridge across the mouth of the Minnesota, Mr. Shepard, the engineer, made borings to ascertain the character of the foundations. A rod was forced down about 60 feet, at which distance a stratum was reached so yielding that the rod's weight would be barely supported. He did not endeavor to probe further, for just before reaching this soft layer he passed through a harder one of sufficient thickness and resistance to support his structure. This bridge is a work of minor character. This shows that the deposit in the old valley exceeds 60 feet at this point. The Minnesota being a muddy stream, its fine silt has much filled the lake which the Mississippi *débris* at its mouth caused.

The *débris* and material brought over and from the falls of Saint Anthony has been carried downward by the water, gradually accumulating and filling the valley as it advanced. One should here stop and consider the manner in which river deposits are made. The finest clay is so easily mingled with the water that the slightest disturbance in the fluid as it moves, even with the gentle currents, is sufficient to keep it from settling down until the still water is reached. The amount of this on the Upper Mississippi is comparatively very small. Such materials as can be moved only by the swiftest currents are rolled over along the bottom, gradually diminishing in size by friction, and furnishing smaller particles susceptible of being thus moved by feebler currents. The resulting material is pebbles, gravel, and sand, the fine material, such as clay and vegetable matter, being all washed out.

When deposits of gravel or sand are made of materials moved along the bottom, it takes place as soon as the current slackens, as it must do on reaching a place having larger sectional area. The deposit is sudden, and the material is all taken up in diminishing the section, until the velocity of transportation is restored; then deposition continues immediately in front of the last deposit. Such deposition, therefore, does not extend laterally from the course of the current into any contiguous dead water, as depositions from water holding a clayey or vegetable matter would.

Thus in the valley of the Mississippi, the lakes alongside the river's course are deeper than the river, which has continued to raise its bed by deposits of sand after the lakes were cut off from its current.

From the Falls of Saint Anthony down to the Saint Croix River the Mississippi Valley receives no considerable tributary. The Saint Croix comes from a region of trap rock now furnishing little or no large and heavy sedimentary matter. The result has been that the Mississippi's deposit of sand and gravel has been thrown across its mouth, holding back its water and forming the Saint Croix Lake. At low water, while the depth of the Mississippi at the juncture is 2½ feet, the depth in Lake Saint Croix is 25 feet. It is not probable that 25 feet depth represents the amount of filling of the ancient valley at this point, because the lake itself must have been somewhat shoaled with fine deposits of clay and vegetable matter.

The next considerable tributary to the Mississippi Valley is the Chippewa. This, entering at right angles with a steep river slope and a probable high-water volume of at least 40,000 cubic feet per second, comes from a region inexhaustibly supplied with siliceous sand and gravel containing a considerable of the heavy magnetic sand, whose oxidation often cements the other sand deposits.* It brings quantities of these materials which, spread out below, give a very steep slope to the Mississippi River and very bad shoals for navigation.

Lying just above this deposit is Lake Pepin, which it completely accounts for. The reason this lake has not been filled up by the Mississippi above is that the supply of sand from the Chippewa is so great as to raise the level more rapidly than the filling above can keep pace with. The Chippewa from the left bank pushes its sand-bar out, so as to confine the outlet to the lake to the opposite shore. There is an observaable relation between the condition of the lake and the deposits of the Chippewa. The deepening of the waters by the deposit of Chippewa sands is felt at low water sometimes as far up as the mouth of the Saint Croix, when floods in the Chippewa make these deposits large, and, on the other hand, in times of droughts the waters of the lake cut the outlet deeper, and lower its level, so that the shoal water is moved down the river two or three miles below the Saint Croix.

If we follow the Mississippi down we find similar conditions produced by the Wisconsin River as by the Chippewa; that is, a great increase of the slope and shoaling of the river below the junction, with gentler slopes, deep water, and lake-like aspect above. There would probably have been a large lake here if the discharge of Black River, just above, had not silted it up.

Another instance is afforded by the damming-back effect of the Mississippi deposit at the mouth of the Illinois River, making it at low water almost like a lake up La Salle.

Lake Pepin must therefore be regarded as due to the deposit by the Chippewa of heavy coarse sediment into the valley of an ancient and larger river. This view may be strengthened further by the following considerations: It lies immediately in the course of the main valley above an important tributary. In this respect it agrees with Lac-qui-parle, on the Minnesota, just above the Lac-qui-parle River; with another lake on the same valley just above the Yellow Earth River; with Big Stone Lake in the same valley, just above Whetstone River; with Lake Traverse, which is formed by deposits from a stream at each end, and this empties sometimes in both directions. It agrees in this relation with the lakes on the Qui-Appellee, which all lie just above a considerable tributary, and with like lakes on the Upper Fox of Lake Winnebago. This constant relation seems unmistakably one of cause and effect.

Valley now filling up.—From what has been stated above, it is clear that the river valley in the part we have considered is not now being deepened by erosions, but, on the contrary, is filling up, and it appears to be doing so all along its lower course except at the rapids.

Recent drainage of Lake Winnipeg southward.—As I have stated in previous reports, I regard the ancient river draining the Winnipeg southward by the Minnesota and Mississippi Valley as existing subsequent to the glacial deposits. This is based upon the fact that the river's course is cut through those deposits, as shown by the banks in many places from Lake Traverse, in Minnesota, to Warsaw, in Illinois, and that the ancient bed of Lake Winnipeg is free from glacial deposits, and exhibits only the silt-deposit since made by the ancient lake itself.

Valley formed since the glaciers began to retire.—It also seems most probable that the ancient valley itself, as a whole, was formed in the region of glacial deposits, partly during the period this great field of ice was receding, and partly since it left the ancient Mississippi Basin, for the following reasons: When this ice-period was on the increase, its southern margin must have been gradually advancing in this region, crushing down and planing off the ridges and filling the ravines and water-courses with the *débris* not only of the neighboring rocks, but with the great mass of hard rocks and other material brought from regions far to the north. There seems a probability that much of the present Upper Mississippi Basin had previously been for long ages exposed only to erosions of streams and of the atmosphere, so that it was probably much cut up and fissured, as we see in regions farther west, where no glacial action has occurred. It must have been an easy matter then for the glacier to have thoroughly filled up all the valleys and ravines, leaving the surface everywhere of the well-known rounded hill and basin forms of the drift regions. Wherever the glacial scratchings are preserved, their uniform directions indicate a massive movement to the southwest quite independent of all influence of underlying inequalities. The water which flowed from them would seek the first lowest line and excavate its course without regard to the nature of the older stratified rocks buried beneath the glacial deposits, and such seems to have been the case, for the valley takes a great variety of courses, running about northward at Saint Paul, due west at Rock Island, and its directions fill every azimuth in different parts from northeast around by south to west. To the old stratified rocks its course seems to have no relation, now cutting across an anticlinal, then following the strike in one direction and again in the opposite one.

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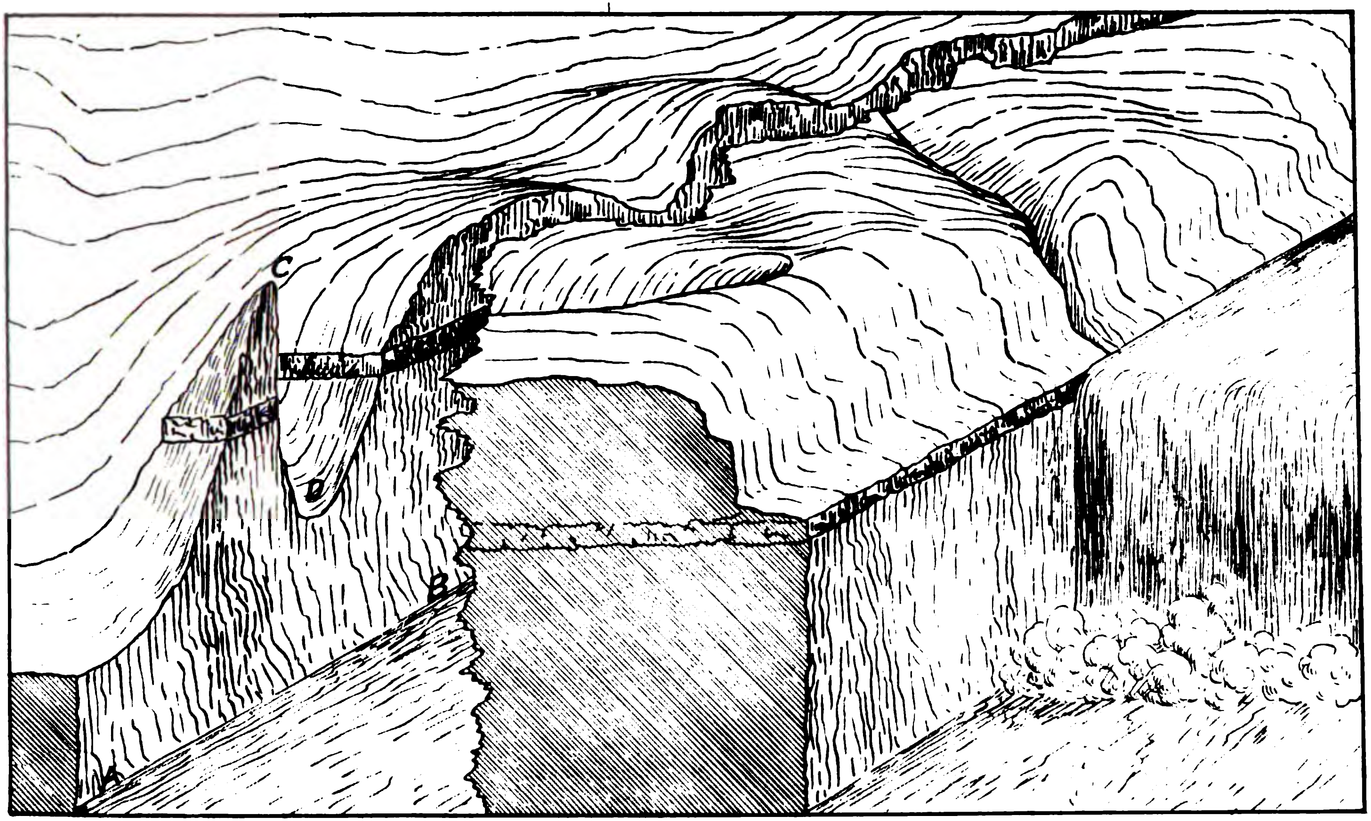
* The analysis of the soil on this part of the Chippewa River (the Yellow Banks) gives 93 per cent. of insoluble matter, which is chiefly white sand, with only 2 per cent. of organic matter, less than 4 per cent. of soluble saline matter, consisting chiefly of oxide of iron and alumina with only a trace of calcareous earth.—(Owen's Report, p. 56.)

How the valley was formed.—At Saint Paul, on the Mississippi, and in the Minnesota above, are the banks of an ancient water-course when at such higher level than now that the river-bed was the magnesian limestone rock, the same as that of the Mississippi, just above the Falls of Saint Anthony. The existing channel of the ancient valley has probably been formed by a cataract in the great river, similar to that at Saint Anthony. This view is sustained by the high islands of rock in the valley of the Minnesota, being remains of strata once continuous across it. These high islands also exist below in the Mississippi, such as Barn Bluff, at the head of Lake Pepin, and the Trempeleau Hills. Some of these detached bluffs may have been formed by bends approaching each other by erosions gradually forming a neck and cutting it off. One such, nearly completed, is seen in the Dalles of the Chippewa River. The period which must have elapsed in doing this work was large, but it is probable that the volume of water, during the melting of the glaciers north of it, was greatly in excess over that of the present drainage of the Winnipeg basin. The period may have been somewhat shortened by the new water-course regaining in places some ancient one, filled only with glacial *débris.*

If we look at the valley shown on the map from Lake Traverse to Rock Island, we see that it gradually widens and contracts along its course, but, as a whole, widens as we descend. It widens where the rocks on the banks are soft, and narrows where they are harder and capable of resisting atmospheric erosion, as they are near Dubuque. This is in accordance with usually received ideas, that where the stream is confined by hard banks, its increased velocity, due to such contractions, may have caused the streams to abrade deeper. It is improbable that the ancient river, where it cut its way either as a cataract or in any other manner of river erosion, made the valley as wide as we now see it.

Warren's Rep't. Bridging Miss. R. Diagram D.



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It most probably underwent subsequent widening from the impinging of the currents against the foot of the high banks, thus removing the *débris* falling from the cliffs above, as well as scouring away the unbroken strata against which it washed. Even now, although the great river has disappeared, we see that the valley is still widening in some places where the river flows at the foot of the high bluffs, although, in the great majority of cases, the atmospheric erosions have covered the steep, rocky scarps with detritus, which, clothed with vegetation, preserves them from the influence of the air. Where the river now impinges against the banks composed of soft strata, we sometimes still see its effect in the fresh-cut appearance of the cliff, and are led to give greater weight to similar operations in the past, when like forces were probably more intense.

I have selected one (Diagram D) such cliff in the wide part of the valley below La Crosse, which part indicates much widening since the first cutting out of the river's course. It is apparent that no stream of water could have cut down from C to A B while the opening D was available. But if we allow that cataract on the right of the diagram represents the conditions when the stream began to flow which cut the valley, then its present course is natural, the subsequent widening bringing it to the state we see on the left of the diagram.

Geologists of high character have estimated the age of the gorge at Niagara Falls on the present rate of recession, and, though the result is uncertain, it indicates the origin to be in recent geological times, although antedating the historical era. In a similar way the time required by the Mississippi to cut the gorge from Fort Snelling to the Falls of Saint Anthony has been calculated by Prof. N. H. Winchell (Report Geological Survey Minnesota, 1876), on data that makes it vary from 6,000 to 12,000 years, by assuming that the forces in producing this result have remained uniform during this period.

That any date in geological time, capable of being expressed in definite numbers of years, can be deduced from existing observations seems highly improbable; but whenever a condition is observed which may be referred properly to the operation of causes now at work, whether of greater intensity or less, it is reasonable to regard the work done as of recent geological origin. We cannot neglect this uncertain method of drawing inferences, since it is the best we have, and we should endeavor, by continued investigation, to make more definite this method of finding the unknown factor, time.

Since the Falls of Saint Anthony were at the junction of Minnehaha Creek, they have receded 6¼ miles. The Minnehaha Falls, since that time, have receded three-fifths of a mile. Both streams have cut into the same formation, starting with the same height of fall. These relative rates have been about as 1 to 10. The proportion of the volumes of the two streams, judging by their present drainage areas, is about as 72 square miles is to 21,600 square miles, or about as 1 to 300. That is to say, the recession of the Minnehaha Falls has been thirty times faster than it would have been if proportionate to the volume. This may be accounted for by the greater atmospheric influence at the smaller falls, which, examination shows, keeps ahead of the effect of the water, forming a cave under the fall by the dropping down of material which the water then washes away. At the greater falls the volume of water almost constantly protects the rocks from the action of the atmosphere. Hence we must give, as said before, a very considerable influence to the operations of the atmosphere in aiding the erosions of small streams, and in demolishing cliffs where the water can remove the *débris*.

I attribute a more recent origin of the gorge of the Mississippi from Fort Snelling to the Falls of Saint Anthony than to that of the Minnesota above the junction. The general map indicates that the same force which formed the valley below the junction formed that of the Minnesota above.

The hypothesis which I have heretofore advanced and endeavored to sustain, that the loss of the Winnipeg outlet along the Minnesota was due to a change of the continental slopes by a northeasterly depression, will explain this more recent origin of the Saint Anthony Falls gorge. This supposed change of slope might have caused a change of outlet of the lakes about the present source of the Mississippi, so that the waters flowed out on the northeast and, falling into a depression leading southward, made this upper part of the Mississippi. When we note the great extent of the eroded valley of the Minnesota, and also the fact that all the smaller streams, like the Saint Croix, Chippewa, Black, and Wisconsin, have cut through the sedimentary rock down to the granitic or trap rocks, it seems improbable that the Mississippi above Fort Snelling, with its greater power, should not have accomplished as much if it had been as long at work.

Regarding the Mississippi Valley as originating as a whole by the action of a stream since the glacial ice occupied its basin, I would note that as far down as the island of Rock Island there is no decided indication of other than successive changes attending such action, and the gradual filling up of the valley by tributary sediment after the great volume of water from the Winnipeg basin had disappeared.

Anomalies of Rock Island Rapids and Des Moines Rapids.—At Rock Island the river has left the ancient valley, which just below Rock River seems lost. We might have supposed that it ended here but for finding it again below Muscatine and continuous down to the Des Moines Rapids, where it is lost again. Just below, however, we find it again, and it then is continuous until it widens out into the broad expanse below the junction of the Ohio, although the river again leaves the main valley, without sufficient apparent cause, at Fountain Bluff and at the Grand Chain.

We had not time to study out where the course of the ancient valley was between Rock Island and Muscatine, but at the Des Moines Rapids we were more fortunate.

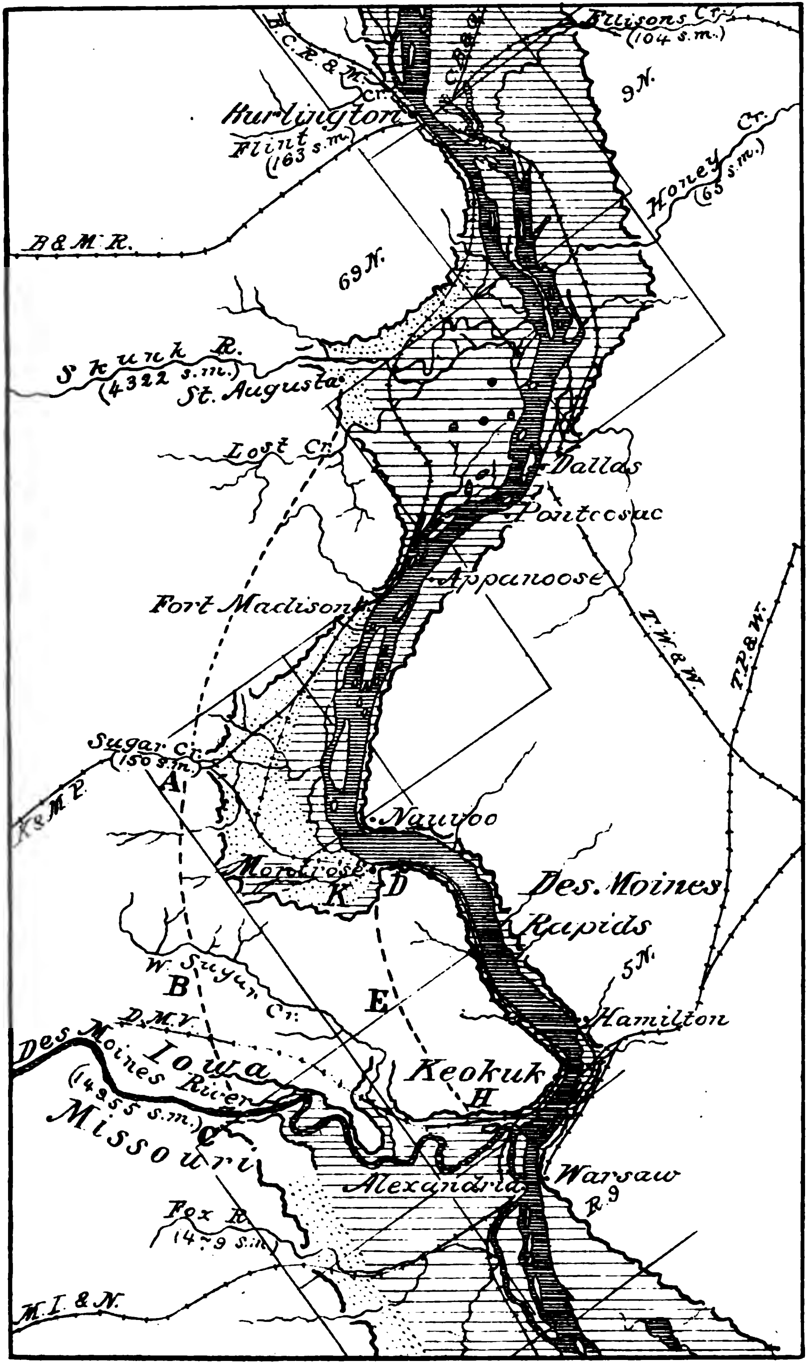
The following description of this vicinity and Diagram E will present the points that appear deserving of consideration.

The river, as it passes the town of Madison on its right bank, which is there 150 feet high, washes against a bluff composed of clay and sand arranged in a manner resembling "the ebb and flow structure." Mr. Worthen gives a good description of this formation in the Iowa Geological Report, vol. 1, part 1, page 187. This kind of bluff is seen only on the right bank, and extends continuously a distance of about 25 miles from the mouth of Skunk River down to the point D (see Diagram E), where it joins the Keokuk limestone rock just back of Montrose.

In descending the river from Madison, the river gradually recedes from this bluff; and a few miles above where Diagram E begins the bluff is 3 miles from the river. A large portion of the intervening space is occupied by a sand terrace, varying from 20 to 50 feet in height above the high-water; the other portion is bottom land, subject to overflow.

The river, before reaching Montrose, has a width within its banks at ordinary stages of about half a mile, and the depth of water in the pools at low stage is from 15 to 20 feet, the bed being of sand, with no rock in

Warren's Rep't. Bridging Miss. R. *Diagram E.*



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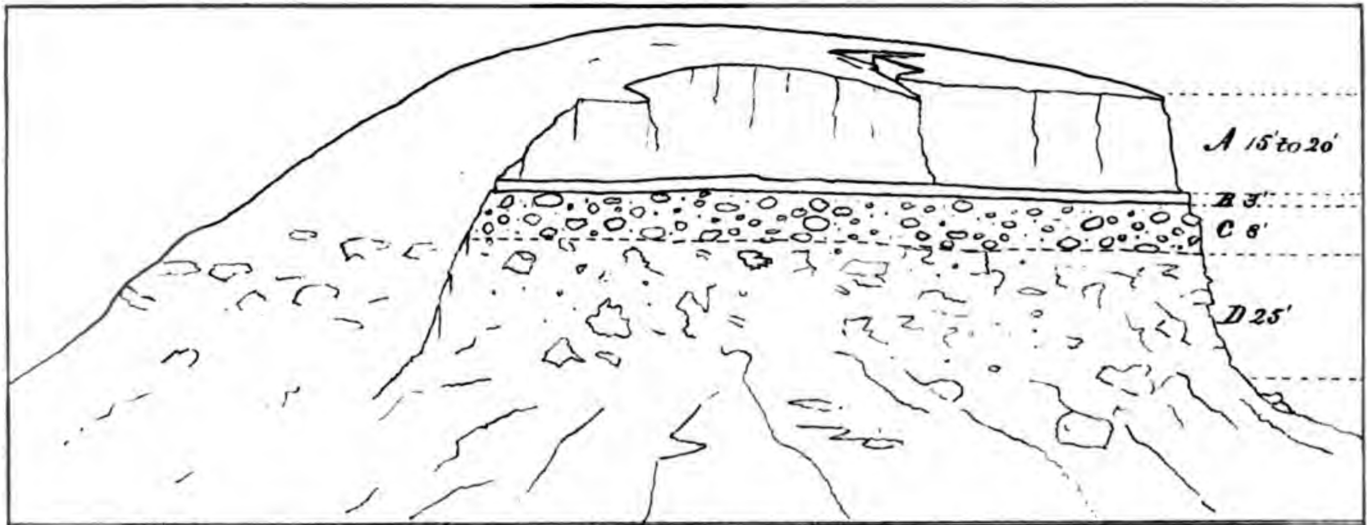
Warren's Rept. Bridging Miss. R.- Diagram F.



Section of Mississippi River Bluffs at Warsaw Illinois

A is a very fine yellow sand and clay widely developed. B is a bluish clay and fine sand C is rounded hard bowlders from small gravel up to 400 lbs., mixed with sand. D is composed of angular blocks from over a ton weight down to small stones, mingled without order; with coarse and fine sand and clay, showing no selection or sorting. The rocks are trap, porphyry, granite gneiss or syenite, hard brecciated limestone &c. The upper carboniferous shales in vicinity exhibit local displacements

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place; nor is there any rock in the right-bank bluffs till just below Montrose, where it begins also in the river-bed. On the left bank or Illinois side the bluffs are of rock, the same as at the rapids, where they have been cut through by the river. This cut begins at Montrose, where the river makes a turn at a right angle to the eastward, but the depth at low-water is only 2 to 3 feet, and the width at ordinary stages has widened to 1 mile. On both sides of the rapids the rock bluffs rise almost immediately from the water. The river on the rapids continues easterly about 2 miles, then turns southward and maintains this direction until all the rapids are passed and for a mile beyond; then turns southwest until the mouth of the Des Moines River is passed, and then turns southward again.

The rock disappears in the bed in passing Keokuk; the water then deepens, flowing on a sandy bed, and resumes its width of about half a mile between its ordinary banks. On the rapids there are no considerable or permanent islands, but as you go above or below, you find them as soon as the rock-bed is left.

At Warsaw, 3 miles below the foot of the rapids, the Carboniferous rocks show in the bluffs, and so does the unmodified glacial drift, covered with the loess. (See Diagram F.)

The Mississippi Valley at Warsaw is about 8 miles wide; part of it a sand terrace, but most of it subject to overflow.

Proceeding up the Des Moines from the mouth, we leave the limestone strata at the point H (Diagram E), and do not meet with it again, either in the river-bed or bluffs, till we reach the point C, where we find it in both places, and thence all along up this valley.

In this distance between H and C the bluffs are only on the left bank or north side, and the material appears similar to that at Madison or to the loess at Warsaw, shown in Diagram F. If we examine the valley of Sugar Creek, we find the bluffs cut down as low as on the Des Moines between H and C, and all of similar material, clay and sand, but no rock in place. Nor could we find on any of the branches between A B C and D E H any rock in place or learn of any. Within these limiting lines those who have dug wells for water find it without reaching rock.

At the place marked K on the sand terrace a well 50 feet deep encountered no rock, although this was as far down as the level of low water in the river.

The width of the main valley above Fort Madison is nearly the same as below Keokuk, and if we prolong the line of bluff between these two places, it will include a space between them where there is no known rock *in situ*, and which it appears reasonable represents the ancient channel, since filled up.

The loess formation.—This name has been given in this country to a fine material deposited over all the other formations, including the glacial deposits near the river, but not upon the river sand and gravel terraces, which are therefore the more recent. It has a thickness of many feet in places. It is generally regarded as having been deposited in quiet water. In many places it is nearly uniform in thickness, conforming with the previous irregularities of the surface, as snow lies where it has not drifted. This would be brought about by a silt-laden fresh-water current spreading out over one more dense and quiet, through which the fine silt dropped. Such conditions would exist in salt water, and the silt would prevent the existence of many kinds of marine life, and would contain the animal remains brought from the fresh-water streams.

The margins of the loess deposit are not well defined, and do not appear to have been investigated as they should be. The deposit is well shown near Rock Island, but does not appear as high up as Dubuque (so far as I know). It extends up the Missouri as far as Sioux City, and the Missouri River made immense deposits into the body of water in which the loess was laid down. From the absence of marine fossils, the body of water has been regarded as fresh and without connection with the Gulf of Mexico except through an outlet. Judging from what I know of the deposits, I should think it did not connect with our present Great Lakes, and that a tongue of land or promontory separated the arms extending up the Mississippi and Missouri Rivers.

The streams which brought this fine loess material which has been so spread out must have brought down heavier material along the bottom that fell as soon as it reached the enlarged section, just as rivers make their deposits of heavy material now on reaching their natural receptacles. A most interesting case in point is in the deposits made in the Great Salt Lake in Quaternary times, where its terraces show a level nearly a thousand feet above its present surface. The streams, like the Weber, built out the terrace at their point of discharge in the fan shape of a river-bar up this terrace level near the ancient shore, and extending back in the river valley, which must then have appeared as a fiord. Although the ancient Weber River deposit diminished in amount as it extended into the ancient lake, it yet terminated quite abruptly. I think, then, there is good reason to regard the bluff-deposits at Fort Madison and vicinity, on the west side of the valley, as belonging to the loess period, and not to glacial times. These deposits are where streams would bring them from the northwest, while the glacial deposits seem to have come from the northeast. This filling up of the ancient valley of Keokuk and Madison, and also in the neighborhood of Rock Island, is where the mouths of considerable rivers probably were during the existence of the large body of water in which the deposition of the loess was made.

Formation of rapids since the loess.—When the body of water of the loess period disappeared and the emergencies of the land again took place, the Mississippi did not regain its ancient channel, but cut the new one now occupied. These rapids cannot be accounted for by any special hardness of the rocks, but their resistance is increased because of the dip of the strata being nearly that of the river-slope. When the river was at a higher level and made the sweeping bend above Montrose so as to wash the loess bluffs, but little more erosion would have been required there to have carried the river back again to its ancient channel during some extraordinary flood, and yet it might have been that the new channel would even after this remain the permanent one for ordinary stages.

Such an explanation as this may be applicable to the cases at Fountain Bluff and at the Grand Chain on the Mississippi just above the mouth of the Ohio, and to the almost incomprehensible changes of course in the Lower Ohio itself, shown on the general map.

Another interesting supposition may be made that the Mississippi in the last Terrace period might have succeeded in washing down the bluffs, separating it near Burlington from the Crooked Creek flowing into the Illinois. (See Diagram 1, sheet 4.) The new channel would have double the descent to the mouth of the Illinois of the existing one, and we might have gained a new course for the river, leaving a larger ancient channel occupied by a smaller stream, and there would have been set at work a new cause to modify all the valley of the Illinois River and all the Mississippi above.

Summary of principal points presented.—I will summarize the principal facts that seem to be made out along the course of the Minnesota and Mississippi:

1. That the Minnesota Valley and the Mississippi Valley above the Ohio have been, as a rule, formed since the deposition of the glacial drift, for this exists in unmodified and modified forms in the banks of the river, and that the Winnipeg basin drained out southward along it.
2. That the loess deposits, extending up to the neighborhood of Savannah, are later than the last glacial drift.
3. That channels like those at the Des Moines Rapids and river terraces in that vicinity are more recent than the loess.

Explanatory hypothesis.—I have advanced this hypothesis of alternate southern elevation and northern depression several times before and illustrated its effect on the Minnesota and on the Wisconsin River, and in the first instance considered what the results would be in contiguous regions, and how far facts seemed to correspond, so it will be unnecessary to repeat them here.

The hypothesis appears to be in accordance with a number of very important facts, and is consistent with observations as to southern elevation and northern depression now going on. It explains, by one widely exerted influence, many effects which, on the grounds of glacial action alone, requires many special glaciers, and it will answer as an explanation of the coming on and disappearance of the loess body of water, and for the change in the drainage of Lake Winnipeg. If we can show that any movement of the earth's crust is a recurrent phenomena it may help us to trace out its cause.

Approximate practical conclusions.—The only conclusion which can be drawn from the preceding discussion seems to be that the origin of the excavation of the valley is comparatively modern, and that it was from the operation of forces producing probably uniform results, and in a way that we have some approximate comprehension of it in general, from our knowledge of special localities.

Sections of best known parts of the valley in regard to depth of bed-rock.—The following-described transverse sections of the main valley with three taken across tributaries just above their junction with it give all the positive data we have in regard to depths to bed-rock. They are shown on Diagram 3. On these the high and low water levels are shown, but it must be kept in mind that the high-water lasts but for so brief a period that it does not prevent trees from growing over nearly all the bottom-lands. The shortness of the time of high-water not only prevents much erosion, but the presence of the trees greatly retards the flow of the water, and makes its currents more gentle than in the ordinary river-channel. Where the bed-rock has been reached on all rivers in this country, it is overlaid by many bowlders, indicating the swift currents which moved such rocks along at the period of greater erosion. These bowlders sometimes form a stratum several feet deep, and often prevent boring-rods from reaching the bed-rock, but whenever they are thus found to be close together they indicate that the bed-rock is not far beneath.

No. 1 is at Big Stone Lake, about 3 miles above the outlet. The width of the lake is about 1 mile; the width between the bluffs is about 1½ miles. The depth of the water is about 6 feet; the rise from low to high water, 5 feet. The bluffs, banks, and bed of the lake are in the drift formation. The depth to bed-rock was not ascertained, but it is believed to be but a few feet below the present bed, as rock appears in the valley at the lower end of the lake. The rock is granitic. No rock *in situ* was found in the bluffs or ravines.

No. 2 is a section 150 miles below No. 1 and 1 mile below the mouth of the Blue Earth River. The river here at low-water is 300 feet in width. The rise from low to high-water is about 28 feet. The depth to rock is not known. At time of high water it reaches from bluff to bluff, a distance of 1½ miles. The lower 40 feet of the bluff is a soft sandstone capped by magnesian limestone about 40 feet thick, and this is covered by drift. This sandstone is called by D. D. Owen, Lower or Potsdam. It is very friable, and when exposed is rapidly eroded by atmospheric changes.

No. 3 is near the mouth of Minnesota River, 72 miles below No. 2. The valley here is about three-quarters of a mile wide between the bluffs. The high-water river extends from bluff to bluff. The low-water width of the river is 350 feet, the depth 12 feet, the rise from low to high water 22 feet. The depth to bed-rock is not definitely known, but is more than 60 feet. The bluffs for the first 80 feet are of soft friable sandstone capped by about 15 feet of hard magnesian limestone, and above this from one-quarter to one-half mile from the river with drift from 50 to 75 feet in height. The base of the bluffs on this section and in the lower part of the Minnesota Valley are protected from erosion by the limestone that has fallen into it, the sandstone being washed away from beneath it.

No. 4 is a section across the valley one-half mile below No. 3, and below the junction of the Mississippi and Minnesota. The low-water width of the river here is about 700 feet, and the high-water width from bluff to bluff about 1½ miles. The rise from low to high water is about 22 feet. The character of the rocks composing the bluffs and their height are the same as in section No. 3. The increased volume of water carries away the greater part of the soil at the foot of the bluffs, so as to leave but little except the *débris* of the limestone fallen from above.

No. 5 is a section of the valley of the Mississippi River immediately above its junction with the Minnesota River. The river occupies nearly the full width between the bluffs, which are less than 1,000 feet apart. The bluffs rise almost perpendicularly from the river, so that it is difficult to find an approach for a carriage-road. The character of the rock composing the bluffs is the same as that in sections 3 and 4 and at Falls of Saint Anthony. The sandstone in these three sections is called the Saint Peter's sandstone by Owen, or No. 3 of the ascending series of the Lower Silurian age, the Potsdam sandstone being No. 1. It is the same as the upper sandstone, or Saint Peter's sandstone, of Hall and Worthen.

No. 6 is a section of the Mississippi Valley at Hastings, Minn., 26 miles below section No. 4. The river here at low-water is about 500 feet wide; at time of high water it extends from bluff to bluff, nearly 1 mile. The low-water depth of the river is about 16 feet. In driving piles for the railroad-bridge no rock was struck, so that the bed-rock is more than 40 feet below low-water. The rock appears on the right bank at low-water, and rises as you leave the river; 1 mile from the river it is about 130 feet high. In the opposite bluff no rock was seen, but it appears a short distance up river. The bluffs are steep, and are from 120 to 200 feet high. The rock composing the bluff is a magnesian limestone, too porous to make a good building-stone, but still a hard stone that withstands atmospheric changes well. The tops of the bluffs are covered with drift of varying depths.

No. 7 is 42 miles below section 6 and near the lower end of Lake Pepin. The width of the lake is about 2½ miles, and the width of the valley is about 3 miles. The low-water depth of the lake is about 60 feet. The rise from low to high water is 17 feet. The bluffs are about

400 feet high; the lower 200 feet is of Potsdam sandstone and the upper 200 of magnesian limestone. The base of the bluffs is protected by a talus of magnesian limestone, which has fallen from the bluffs above. The depth to bed-rock is not known.

No. 8 is a section of the valley near La Crosse, Wis., 62 miles below section No. 7. The low-water width of the river here is about 1,300 feet, the high-water width is about .4 miles. The rise from low to high water is about 16 feet. The valley from bluff to bluff is about 5 miles wide, about one mile being occupied by a sand terrace above overflow. The rock of which the bluffs are composed is a soft sandstone (Potsdam) for about 320 feet above low water, capped with 15 feet of magnesian limestone. The depth to the bed-rock in the valley is not known. In building the railroad-bridge at this place, piles were driven to a depth of 60 feet below low-water and no rock struck.

No. 9 is a section of the valley at Prairie-du-Chien, Wis., 56 miles below No. 8. The low-water river here is divided by an island into two channels with a total width of 1,800 feet. The rise from low to high water is about 22 feet. The width of the river at high water is about 1¼ miles. The whole width of the valley is about 2½ miles, 1¼ miles on the left or east side being occupied by a sand terrace, upon which the town of Prairie-du-Chien is built. The bluffs from the first 165 feet above low-water are of magnesian limestone, the next 60 feet of a soft sandstone (upper or Saint Peter's), capped by 175 feet of magnesian limestone, covered with drift of varying depths. The depth to bed-rock is not known. It is probably in excess of 50 feet below low water, as it has not been struck in driving piles in the river, and some in the deepest water must have reached nearly to that depth.

No. 10 is a section of the valley at Dubuque, Iowa, 55 miles below No. 9. The low-water width of the river is about 1,700 feet, the high-water width of the river is about 1 mile, and extends from bluff to bluff. The rise from low to high water is about 20 feet. The depth of the low water is about 16 feet. The depth to bed-rock is not known, but it is greater than 40 feet below low water. The bluffs are of limestone, about 200 feet in height. This limestone is known as the Galena limestone. It is dolomite, being composed of nearly equal parts of lime and magnesia. It is a hard stone, but not uniformly so; some parts eroding more rapidly than others give the bluffs a castellated appearance. In the crevices of this formation nearly all of the lead of this section has been found. The want of homogeneity prevents this stone being much used for building purposes. The base of the bluffs and the river banks are completely covered with the *débris* from the bluffs. The peculiar feature of this section—its narrowness—may be due to the resistance of the rock to erosion.

No. 11 is a section of the valley at Rock Island, Illinois, 88 miles below No. 10. The river is here divided into two channels by the island of Rock Island; the whole width of the river is 2,800 feet. The low and high water widths are nearly the same, the banks rising nearly perpendicularly. The rise from low to high water is 16 feet. The bed of the river, the island, and lower part of the bluffs are of limestone, somewhat hard and much fractured. The tops and sides of the bluffs are covered with drift and loess. The whole width between the bluffs is about 1½ miles. This section is across the valley near the lower end of Rock Island Rapids which extend from Le Claire, Iowa, to Rock Island, a distance of 14 miles. The bed of the river throughout this distance is of limestone of the same character as at this section.

No. 12 is a section of the valley at Burlington, Iowa, 65 miles below

No. 11. The low-water width of the river here is about 2,500 feet, the high-water width is from bluff to bluff, a distance of nearly 5 miles. The rise from low to high water is 20 feet. The depth of bed-rock is not known. Piles driven for the railroad-bridge did not reach rock except for a short distance from the west shore. The bed-rock must therefore be more than 40 feet below low water, as piles in 10 feet water were driven 30 feet or more into the sand. The bluffs here are 100 to 150 feet high. The lower 30 feet of the bluff on the right bank is composed of sandstone and green shale, referred by Hall to the Chemung Group of New York. It is soft and erodes rapidly when exposed. This is capped by 100 feet or more of Burlington limestone. In the opposite bluff no sandstone is seen, the Burlington limestone only being exposed. Its height is about 100 feet.

No. 13 is a section of the valley at Keokuk, Iowa, 40 miles below No. 12. The low-water width of the river is 2,600 feet. The high-water width is from bluff to bluff, 1¼ miles. The rise from low to high water is 22 feet. The bed of the river is of rock throughout. It is a cherty limestone, which resists erosion because the dip of the strata corresponds closely with the slope of the river. The bluffs are from 100 to 150 feet high. The bluff on the right bank is 150 feet high, the first 100 feet above the river being of limestone capped by 50 feet belonging to the Coal-Measures overlaid by drift. The bluff on the left bank has the same limestone but no exposure of rock representing the Coal-Measures. This section is near the foot of Des Moines Rapids, which extend up to Montrose, 11 miles above. The bed of the river throughout this distance is rock of the same character as at the section.

No. 14 is at Quincy, Ill., 32 miles below No. 13. The low-water width of the river is 3,000 feet. The high-water width of the river is about 4½ miles. The rise from low to high water is 20 feet. The depth to bed-rock in that part of the valley occupied by the low-water river is from 40 to 50 feet below low water. The width of the valley from bluff to bluff is about 6½ miles. The bluff on the right bank is about 100 feet high, of mountain limestone, covered by drift of varying depths; that on the left bank has 100 feet of the same formation capped by 30 or 40 feet of drift. The depth of the bed-rock is taken from the report by Mr. T. C. Clarke, civil engineer, chief-engineer of the Quincy railroad-bridge.

No. 15 is at Louisiana, Mo., 4 miles below No. 14. The low water width of the river is about 3,200 feet. The high-water width is from bluff to bluff, or 5¼ miles. The rise from low to high water is 20 feet. The depth to bed-rock was furnished me by Mr. E. L. Corthell, chief engineer of Sny Carte Levee Company. The greatest depth on this section below low water is about 80 feet. It is not improbable that this depth may be from 10 to 20 feet short of bed-rock. The borings for this section were made with a seven-eighth-inch diameter rod, jointed in lengths of 10 feet, and forced down by manual labor, men turning and thrusting alternately by means of handles secured to the rod by set-screws. The lower end of the rod was armed with an auger point, making one turn or thereabouts. The bluff on the right bank is about 300 feet high. In this bluff we have rocks of the Lower and Upper Silurian, Devonian, and Sub-Carboniferous ages. In the opposite bluff the same, except the Lower Silurian. This upheaval or tilting up of the older rocks continues to Cap au Gris where the upper or Saint Peter's sandstone forms a bluff of more than 100 feet in height. Immediately below Cap au Gris is a "downthrow"; all of the older formations disappear and we have a bluff composed wholly of Sub-Carboniferous limestone.

No. 16 is at Saint Louis, Mo., 86 miles below No. 15. The low-water width of the river here is about 1,500 feet; the high-water width of the river is about 6 miles. The rise from low to high water is 41 feet. The greatest depth to the bed-rock, as determined in that part of the valley occupied by the low water river, is 90 feet. The width of the valley between the main bluffs is about 7½ miles. On the right bank the rock appears at the river's edge at low water, and rises gradually to a height of 100 feet; above this the drift or loess is in varying thickness from 20 to 60 feet. The rock is a hard limestone. On the left bank limestone is found to about the same height, overlaid by drift or loess. The eastern part of the valley on this section is the great American bottom. Most of this is above the usual high-water; extreme high waters, however, overflow the greater portion of it.

No. 17 is a section of the Mississippi Valley at Fountain Bluff, Ill., 88 miles below No. 16. The low-water width of the river is about 2,600 feet; the high-water width is about 3 miles. The rise from low to high water is about 44 feet. The bluffs are 200 to 300 feet high. The river, except at times of high water, flows between the main bluff on the right bank and Fountain Bluff. Fountain Bluff is an isolated bluff standing in the valley; it is about 4½ miles long and 1¾ miles wide in its widest part. The lower 50 feet of this is of limestone, capped by upward of 200 feet of conglomerate of the Coal-Measures. The bluff on the right bank is of the same formation, but not so high. The bed of the low-water river is rock. In that part of the valley between Fountain Bluff and the main bluff, east of the Big Muddy River, the depth to bed-rock is not known, but it is believed to be far greater than in that part occupied by the low-water river. The main bluff on left bank is of limestone. Immediately below this section an "upheaval" brings rocks belonging to the Upper Silurian age to the surface. "Devil's Oven," "Grand Tower," and "Back Bone" are of these rocks.

No. 18 is at Commerce, Mo., 35 miles below No. 17. The low-water width of the river is about 700 feet; the high-water width is from bluff to bluff about 3,400 feet. The rise from low to high water is 48 feet. The bed of the river is of rock from bluff to bluff; rock rises above low water except in the low-water channel. These bluffs and the bed of the river is a limestone belonging to the Lower and Upper Silurian. This section is of special interest by reason of its narrowness. The distance between the bluffs is less here than at any place between Lac Traverse and the mouth of the Ohio. An opening in the bluffs on the right bank between Cape Girardeau and Gray's Point, some 5 miles above this section, leads through to the Whitewater River. This opening, some 3 miles in width, before the building of a levee across it, carried off a portion of the flood-waters of the river. In 1844 it was overflowed to a depth of 12 feet.

No. 19 is a section of the Missouri Valley at Saint Charles, Mo., where the river debouches into the Mississippi Valley. The low-water width of the river is about 2,000 feet; the high-water width is about 2 miles; the rise from low to high water is 40 feet; the depth to bed-rock in the part shown is about 75 feet; the width of the valley from bluff to bluff is about 2¼ miles; the rock in the bluffs for 50 to 70 feet above low water is of limestone. This is capped by from 40 to 70 feet of drift and loess.

This section of the Missouri was furnished by General C. Shaler Smith, civil engineer, chief engineer of the Saint Charles Railway bridge.

No. 20 is a section of the Illinois River Valley, about 5 miles above the mouth of the river. The high-water width of the river is about 2 miles; the rise between low and high water is about 39 feet; the width of the valley between the bluffs is about 2¼ miles; the bluffs are about 150 feet high and of limestone.

Contour map of the sources of the Mississippi.—We have prepared a small contour map of this region, using all the available determinations of elevations above the sea. It would take considerable space to acknowledge the sources individually; the large collection of this data made by Mr. Gannett, member of the Geological Survey of the Territories, has been particularly useful. But the drawing of the lines has been mainly the result of our own knowledge of the region. Contour lines are given for each 200 feet from 600 feet up to 2,000 above the sea-level. The object of making this map is to show the important position in this system of contours occupied by the Minnesota River.

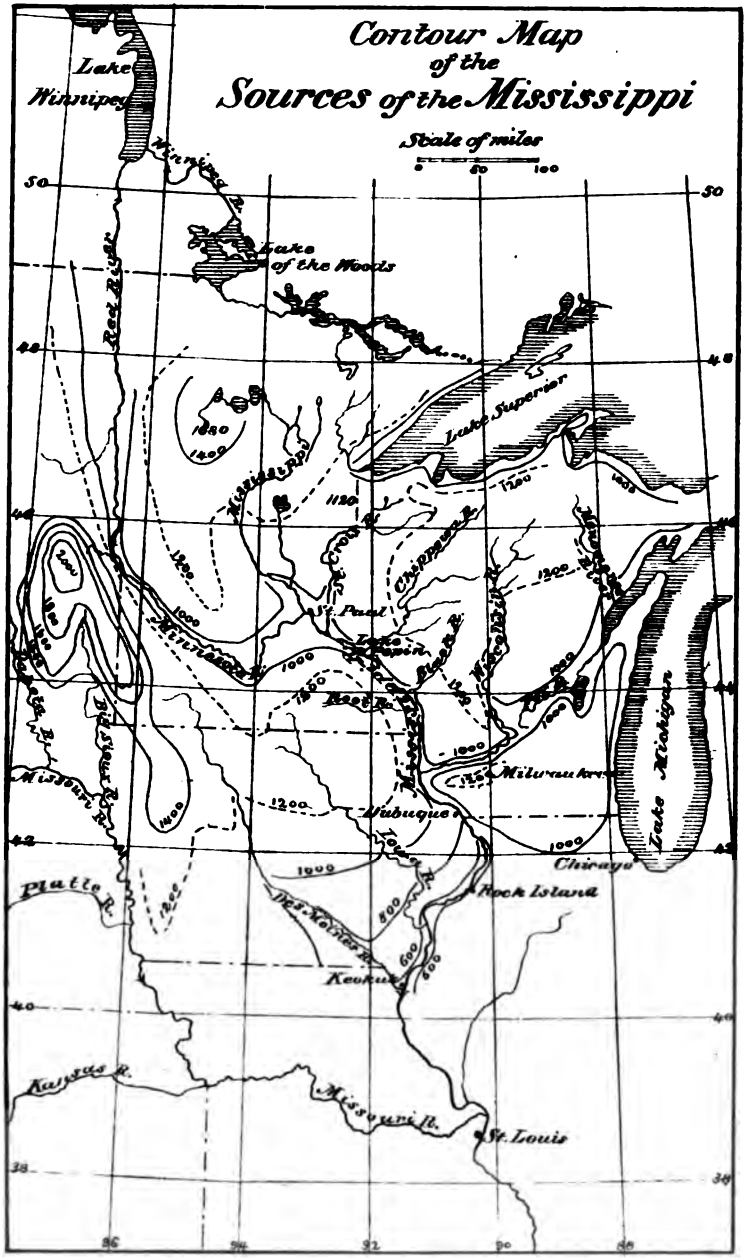
We have also prepared a table giving the area drained by each tributary of the great valley down to and including the Ohio. This will be found useful for many purposes. As a matter of interest to the curious, it may be noted that if the area of the present Lake Winnipeg basin be added to that of the Mississippi, above the junction of the Missouri, it will about equal the area of the basin drained by the Missouri.

Table of areas of basins drained by the tributaries to the valley.

Name.	Miles drained.	Total miles drained.	Distance apart.	Total distance.	Right bank.	Left bank.
Minnesota River	310	310	......	......	R. B.	......
Whetstone or Izuza River	110	420	30	30	R. B.	......
Yellow Banks River	340	760	6	36	R. B.	......
Pomme de Terre River	960	1, 720	13	49	......	L. B.
Lac-qui-parle River	830	2, 550	15	64	R. B.	......
Chippewa River	1, 970	4, 520	10	74	......	L. B.
Yellow Medicine River	650	5, 170	20	94	R. B.	......
Chetomba or Hawk Creek	470	5, 640	1	95	......	L. B.
Redwood River	770	6, 410	20	115	R. B.	......
Beaver Creek	240	6, 650	2	117	......	L. B.
Big Cottonwood River	980	7, 630	37	154	R. B.	......
Little Cottonwood River	245	7, 875	4	158	R. B.	......
Blue Earth River	3, 350	11, 225	16	174	R. B.	......
Cherry Creek	57	11, 282	15	189	R. B.	......
Little Le Sueur River	144	11, 426	7	196	R. B.	......
Rush River	102	11, 528	2	198	......	L. B.
High Island Creek	75	11, 603	6	204	......	L. B.
Sand Creek	234	11, 837	18	222	R. B.	......
Carver Creek	100	11, 937	1	223	......	L. B.
Credit River	140	12, 077	15	238	R. B.	......
Nine Mile Creek	42	*12, 119	2	240	......	L. B.
Mississippi River	21, 600	33, 719	9	249	......	L. B.
Saint Croix River and Lake	7, 568	41, 287	30	279	......	L. B.
Vermillion River	237	41, 524	3	282	R. B.	......
Trimbelle River	95	41, 619	9	291	......	L. B.
Cannon River	1, 639	43, 258	5	296	R. B.	......
Isabelle River	73	43, 331	5	301	......	L. B.
Rush River	183	43, 514	4	305	......	L. B.
Chippewa River	9, 602	53, 116	18	323	......	L. B.
Beef River	452	53, 568	9	332	......	L. B.
Zumbro River	1, 366	54, 934	9	341	R. B.	......
Whitewater River	382	55, 316	1	342	R. B.	......
Eagle Creek	158	55, 474	9	351	......	L. B.
Rolling Stone Creek	136	55, 610	6	357	R. B.	......
Trempeleau River	700	56, 310	10	367	......	L. B.
Black River	2, 880	59, 190	18	385	......	L. B.
La Crosse River	463	59, 653	......	385	......	L. B.
Root River	1, 685	61, 338	4	389	R. B.	......
Raccoon Creek	139	61, 477	7	396	......	L. B.
Crooked Creek	70	61, 547	3	399	R. B.	......
Badaxe River	180	61, 727	7	406	......	L. B.
Upper Iowa River	939	62, 666	3	409	R. B.	......
Paint Creek	70	62, 736	25	434	R. B.	......
Yellow River	279	63, 015	4	438	R. B.	......
Wisconsin River	11, 850	74, 865	7	445	......	L. B.
Turkey River	1, 679	76, 544	21	466	R. B.	......

* Total of Minnesota Rivers.

Warren's Rep't Bridging Miss. R. Diagram G



A.H. PHOTO-LITHO. CO. N.Y. (OSBORNE'S PROCESS.)

Table of areas of basins drained by the tributaries to the valley—Continued.

Name.	Miles drained.	Total miles drained.	Distance apart.	Total distance.	Right bank.	Left bank.
Grant River	289	76, 833	13	479	......	L. B.
Platte River	306	77, 139	6	485	......	L. B.
Little Makoqueta	150	77, 289	3	488	R. B.	......
Catfish Creek	75	77, 364	7	495	R. B.	......
Big Menomonee Creek	32	77, 396	4	499	......	L. B.
Simsinawa Creek	50	77, 446	4	503	......	L. B.
Tête de Mort Creek	45	77, 491	1	504	R. B.	......
Fever River	185	77, 676	3	507	......	L. B.
Mill Creek	35	77, 711	7	514	R. B.	......
Makoqueta River	1, 863	79, 514	7	521	R. B.	......
Apple River	245	79, 819	4	525	......	L. B.
Rush Creek	85	79, 904	2	527	......	L. B.
Plum River	280	80, 184	6	533	......	L. B.
Wapsipinicon River	2, 490	82, 674	28	561	R. B.	......
Rock River	10, 690	93, 364	25	586	......	L. B.
Copperas Creek	25	93, 389	26	612	......	L. B.
Iowa River	12, 250	105, 639	15	627	R. B.	......
Edward's River	43	105, 682	2	629	......	L. B.
Pope Creek	135	105, 817	4	633	......	L. B.
Henderson River	625	106, 442	18	651	......	L. B.
Flint Creek	165	106, 607	4	655	R. B.	......
Ellison's Creek	104	106, 711	3	658	......	L. B.
Honey Creek	65	106, 776	5	663	......	L. B.
Skunk River	4, 322	111, 098	1	664	R. B.	......
Sugar Creek	150	111, 248	18	682	R. B.	......
Des Moines River	14, 955	126, 203	32	714	R. B.	......
Fox River	479	126, 682	4	718	R. B.	......
Bear Creek	418	127, 100	15	733	......	L. B.
Wyaconda Creek	480	127, 580	5	738	R. B.	......
Fabius River	1, 590	129, 170	13	751	R. B.	......
North River	465	129, 635	2	753	R. B.	......
Mill Creek	96	129, 731	3	756	......	L. B.
McDonald's Creek	140	129, 871	13	769	......	L. B.
Salt River	2, 741	132, 612	18	787	R. B.	......
Noix Creek	52	132, 664	3	790	R. B.	......
Buffalo Creek	40	132, 704	1	791	R. B.	......
Bobb's Creek	90	132, 794	13	804	R. B.	......
Gwinn's Creek	25	132, 819	2	806	R. B.	......
Bryant's Creek	75	132, 894	19	825	R. B.	......
Cuivre Creek	1, 180	134, 074	9	834	R. B.	......
Piroque Creek	90	134, 164	3	837	R. B.	......
Dardenne Creek	110	134, 274	6	843	R. B.	......
Illinois River	27, 465	161, 739	8	851	......	L. B.
Big Piasa Creek	100	161, 839	10	861	......	L. B.
Missouri River	518, 000	679, 839	10	871	R. B.	......
Wood River	145	679, 984	......	871	......	L. B.
Cahokia Creek	400	680, 384	17	888	......	L. B.
Meramec River	3, 715	684, 099	18	906	R. B.	......
Eagle Creek	70	684, 169	7	913	......	L. B.
Platin Creek	110	684, 279	5	918	R. B.	......
L'isle de Bois Creek	50	684, 329	9	927	R. B.	......
Establishment River	110	684, 439	6	933	R. B.	......
Rivière aux Vases	100	684, 539	4	937	R. B.	......
Saline River	240	684, 779	12	949	R. B.	......
Kaskaskia River	5, 660	690, 439	7	956	......	L. B.
Saint Mary's River	215	690, 654	4	960	......	L. B.
Brazos Creek	40	690, 694	24	984	R. B.	......
Big Muddy River	2, 245	692, 939	6	990	......	L. B.
Apple Creek	200	693, 139	1	991	R. B.	......
Clear Creek	135	693, 274	18	1, 009	......	L. B.
Ohio River	......	......	42	1, 051	......	......

NOTE.—When I made my first published statement, in 1868, that the drainage of the Winnipeg basin had formerly been southward along the Mississippi, I regarded it in a great measure as a discovery made by myself, and still think so. Recently I have found in the fine publication on "The Principal Diseases of the Valley of North America," by Daniel Drake, M. D., published in 1850, on p. 20, vol. 1, the following:

"A wide and deep current from the north must have excavated this trough across the continent, and Lake Traverse and Big Stone Lake are but hollows or chasms left filled with water when the river ceased to flow. They are long, narrow, serpentine, and lie in the course of the obsolete water. They resemble the pools of a wet-weather stream during a drought, or, more exactly, the crescent lakes of the Lower Mississippi, which, as we shall hereafter see, were once portions of its ancient channels."

The statement that Lakes Traverse and Big Stone resemble "more exactly the crescent lakes of the Lower Mississippi" shows that the character and significance of the lakes were not understood by the writer. They are not lakes left by bends of the river which made what is called a cut-off. They are straight, not serpentine. They occupy all the low valley, not a part of it, as cut-off lakes do. Such general remarks on the subject are found in many writers, but they are vague or incorrect, so that they possess no pointed significance, and are read without making any distinct impression upon the mind.

CHAPTER III.

GENERAL PRESENTATION OF REQUIREMENTS AND ADVANTAGES OF WESTERN RIVER NAVIGATION.—NECESSITY FOR WIDE, CLEAR SPANS AND HIGH BRIDGES; AND A DISCUSSION OF THE DATA ON UPPER MISSISSIPPI FOR DETERMINING HEADWAY UNDER BRIDGES.

Preliminary remarks—How steamboats are constructed—Necessity for high pilot-houses—Height of chimneys—Table of dimensions of steamboats—Barge transportation—Rafting—General remarks—Knowledge of varying stages important—Gauge data used—Gauge observations at Saint Louis and Rock Island compared for a period of sixteen years—Gauge observations at Saint Louis, Quincy, and Rock Island compared for a period of eight years. HEADWAY UNDER BRIDGES: 1st. Saint Louis tables, &c.—2d. Rock Island tables, &c.; comparison of conditions at Saint Louis and Rock Island with regard to headway—3d. Quincy tables, &c.; comparison of conditions at Saint Louis and Quincy with regard to headway—4th. Dubuque tables, &c.; comparison of conditions at Saint Louis and Dubuque with regard to headway—5th. Other places on the Mississippi where gauge observations have been made—General rule for equating headway at places having different ranges from high to low water—Table of ranges from low to high water on the Mississippi, Ohio, and Missouri Rivers.

Preliminary remarks.—When the bridging of the Ohio River at Wheeling was completed in 1849, the bridge was to meet the wants of a public highway (the "National Road"). The railroad system of the United States was then in its infancy, and the canal systems of the country were approaching their highest development. Compared with land or canal transportation west of the Alleghany Mountains, that of the steamboats was speedy, commodious, and luxurious.

The shallowness and other peculiarities of the Western rivers had developed a class of steamboats unlike anything to be found elsewhere, and admirably adapted to the conditions in which they were employed, and which, to a great extent, still exist, and will continue to exist, although in a large part of the Mississippi Basin (where rapidity of transit from place to place is required) they are now of less importance than railroads.

How steamboats are constructed.—As essential to the full benefits of this navigation, the hull of the vessel must be lightly timbered, broad, flat-bottomed, and but a few feet in depth. This shape is rendered necessary by the shoalness of the river at ordinary low-water stages. In practice the deck rises but a little above the water, varying from a few inches to ten feet.

The boilers are high-pressure, of horizontal tubular form, with flues, and are placed side and side on the main-deck. The boiler-deck next above is laid at as low height as will give proper free space above the boiler and also allow room for storing fuel and the bulky freight which forms much of their cargo.

The means of supplying fuel has been an important factor in the construction of the Western-river steamboats. Cord-wood suitable for their use was at first everywhere to be procured along the banks. Its bulk required considerable room for storage, conveniently located with reference to the boilers, to be readily used, and also to be easily taken on board from the banks or from scows alongside.

Coal is rapidly taking the place of wood, but it requires nearly the same arrangements; for although taking up less room, its weight requires it to be frequently renewed, and most of the boats run upon rivers, or are liable to, where wood must be used. Therefore grate-bars are generally adapted to the use of both wood and coal. Where the coal is sulphureous, coal and wood are used together.

The cabin for passengers, covered by the hurricane-deck, comes next above the boiler-deck, and is of sufficient height for comfort and ventilation. Above the hurricane-deck is another cabin called "the texas," allotted to the crew. Upon the texas the pilot-house is placed.

Necessity for high pilot-houses.—The elevated position of the pilot-house is of very great importance, and the reasons for it will be given. The channels of best water are all the time changing, and differ in position one season with another, so that the pilot has to find the best water by means of the indications on its surface made by underlying shoals or obstructions. This can only be done in daylight, and in order to run at night, the pilot must take landmarks in the day-time to be his guide after dark.

A great amount of ready knowledge is thus necessary to pilots on regular lines of steamboats which run at night. In this elevated position the pilot is enabled to see well around his boat, astern as well as forward; has a better view of the signs of deep and shoal water when the water surface is not obscured by mists; commands a better view of the shores and objects upon it which are his marks in the night; and is often for some hours able to see over the mists rising from the water after the view from the main-deck and lower parts of the vessel has been lost. Many hours of navigation are thus saved and delays prevented which would seriously injure business.

Everything depends upon the pilot, and his knowledge and skill, so that the elevated position of the pilot-house is essential. But not only this; the whole arrangement of the boat is designed to facilitate the pilot's command over her movements.

All the side-wheel boats have separate engines for each paddle-wheel, to be used singly as the pilot may direct, and bells are arranged for him to signal to the engineers, generally too complicated to admit of any lowering of the pilot-house to pass under a bridge, without liability of destroying the certainty of their indications, any misinterpretation of which might destroy the vessel at once.

The side-wheels are placed far aft, to facilitate the handling of the boat, and very wide rudders are employed. Stern-wheel boats are much less manageable than the others, except in towing, and there, by means of ropes from the tug to the "tow," compensation is made for having but one paddle-wheel.

The boats running on the Ohio to Pittsburgh in 1849 had pilot-houses about 48 feet above the water, and the length of the boats was about 230 feet. In order to afford proportionally commanding view to the pilot on boats of greater length, the pilot-houses would have to be increased in the same ratio, so that one of 300 feet length would require a height of about 60 feet. This is about the actual conditions of existing practice.

The Thompson Dean, a Saint Louis and New Orleans packet, being 306 feet long, top of pilot-house 67 feet above water; some few feet of this in excess of this ratio (made for ornament) might be dispensed with without practical injury.

Height of chimneys.—In all the practice, until very recently, the reliance for draught in the furnaces has been the effect produced by high and large chimneys. It was shown in the suit against the Wheeling bridge that the chimneys could not be shortened without loss of power and speed, and that attempts to employ shorter pipes and blowers has been made and failed.

Where the navigation has never been obstructed by bridges interfering with the height of chimneys, this practice, founded on experience, has not been departed from. Besides giving draught, the sparks coming out at such great height fall overboard or are cooled, so as to not engender fires when falling on the decks, as they would with low chimneys. Chimneys of boats on the Ohio in 1849 were near 80 feet above water in some cases; their diameter was not less than 5 feet, and their weight near two tons each.

The height of chimneys increased as the boats were built larger, till on the James Howard, in 1874, the chimneys were 104 feet above the water, and those of the Great Republic were said to be higher.

The navigation interests on the Upper Mississippi seem willing now to concede that if the bridge is high enough to allow the pilot-houses to pass under it at high water, the experience they have had in shortening their pipes and adding blowers will enable them to make pipes that shall extend only 8 or 10 feet above the pilot-house of such size as to be easily lowered. The pipes must be at least this high above the pilot-house to prevent the pilot being interfered with by the smoke.

Tables of dimensions of steamboats.—The following tables, giving the heights of different parts of different vessels, are taken from the report of the Board of Engineers on the bridges of the Ohio River and the report of the Board of Engineers on the Saint Louis bridge. The former is contained in Annual Report Chief of Engineers for 1871, page 448, the latter in Annual Report Chief of Engineers for 1874, vol. 1, pp. 648, 649.

Names and dimensions of some of the largest boats employed on the Ohio River above Cincinnati.

Names of boats.	Top of pilot-house above water.		Top of texas above water.		Top of cabin above water.		Top of chimneys above water.		Length of boat.		Width over all.	
	Ft.	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Fleetwood	48	0	34	0	29	0	75	0	260	0	70	0
Telegraph	47	3	34	3	29	0	77	0	251	0	68	0
Saint Charles	47	0	34	6	26	2	68	0	273	0	70	0

Names and dimensions of some of the largest boats employed on the Mississippi River, and which pass the city of Saint Louis, Mo.

PASSENGER-PACKETS.

Names of boats.	Top of pilot-house above water.		Top of texas above water.		Top of cabin above water.		Top of chimneys above water.		Length of boat.		Width over all.	
	Ft.	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
James Howard	69	0	...	...	...	...	104	0	...	...	...	...
Thompson Dean	67	0	46	4	36	8	91	4	306	0	79	4
Phil. Sheridan	65	8	36	2	27	8	72	8	222	0	62	0
J. H. Johnston	65	8	36	2	27	8	72	8	246	0	62	0
Andy Johnson	63	2	36	2	27	8	80	8	273	0	72	0
Jo Kinney	62	3	35	9	27	0	75	9	241	6	65	0
Tom Jasper	62	0	37	6	27	10	72	0	257	0	68	0
Richmond	61	2	45	0	35	5	97	5	340	0	80	0
John A. Scudder	59	7	43	10	34	2	94	2	306	0	88	0
Dexter	59	0	44	0	33	10	87	10	340	0	89	0
Grand Tower	58	4	41	0	32	0	90	0	276	0	73	0
Lucy Bertram	58	4	34	4	26	2	76	2	250	0	67	0
Continental	57	0	40	6	31	4	83	4	288	0	73	0
City of Helena	56	10	40	4	31	4	93	4	277	0	74	0
Pauline Carroll	56	8	42	0	32	0	88	0	266	6	77	0
Belle of Memphis	56	0	40	0	31	0	93	0	273	0	72	0
Exporter	55	0	39	0	32	0	77	0	238	0	62	0
City of Chester	55	0	38	10	30	0	84	0	250	0	70	0
Henry Ames	54	10	39	9	31	0	83	0	305	0	74	0
Julia	54	8	34	8	27	4	83	4	243	6	70	0
Emma C. Elliott	53	8	38	0	28	3	82	3	222	0	63	6
Commonwealth	53	0	39	0	30	0	84	0	264	0	73	8
Illinois	52	9	35	3	27	8	67	8	210	0	50	0
Susie Silver	52	4	37	2	28	0	86	0	265	0	68	0
John Kyle	52	1	38	3	31	1	83	1	299	0	78	6
P. W. Strader	51	8	35	8	26	8	80	8	233	0	56	6
City of Quincy	50	10	36	10	29	6	79	6	280	0	78	0
Rob Roy	50	4	36	0	27	4	79	4	273	0	73	0
Lake Superior	49	9	35	0	27	8	76	8	245	0	64	0
Clinton	49	9	35	11	27	8	73	8	253	0	65	0
Northwestern	46	7	29	11	21	7	65	7	257	0	72	0
Fanny Keener	46	5	33	11	25	7	67	7	208	0	40	0

Great Republic, not in port, higher than that of any on this list, and runs to sugar refinery and elevator, above the bridge.

TOW-BOATS.

Names of boats.	Height of pilot-house above water.		Height of chimneys above water.		Length over all.		Width over all.	
	Ft.	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Mohawk	64	3	78	3	189	0	35	0
Future City	51	0	75	5	222	0	46	4
Saint John	37	8	59	0	200	0	44	0
Atlantic	37	8	64	8	191	0	33	5

Crescent City, Mary Alice, and Bee, not in port, are as high as, and two of them are higher than, those given in the above list.

Among the above-named boats the Phil. Sheridan has run as a regular packet between Saint Louis and Saint Paul, but those best adapted to the trade are of the size of the Lake Superior.

The foregoing is intended only as a general presentation of the question of steamboat navigation with reference to bridges on Western rivers.

I would specially call attention to the reports of the two boards of engineers just quoted from, as giving much more complete presentation of the subject in the special cases treated.

Barge transportation.—At the time the Wheeling bridge was built, in 1849, the system of transportation of coal down stream from Pittsburgh by means of large assemblages of flats and barges, pushed and guided by tug-boats, had not come into use. A draw space of 200 feet between the piers was considered sufficient provision for all requirements, and some thought that 100 feet was ample.

The barge system had, however, come into important use by the time the Steubenville Bridge Company made efforts to obtain legislation in Congress authorizing a bridge across the Ohio River. A width not less than 300 feet in the clear was established by the law, but the coal-navigation interests strove to secure not less than 500 feet. This width is only needed by the heavily-loaded descending tows. Only the empty barges are taken back up stream, and less width is required for them. Subsequent laws of Congress require spans of not less than 400 feet in the clear on the Ohio below the mouth of the Big Sandy River, and one bridge is just finished in a bend at Cincinnati giving a clear span of 500 feet.

The necessity for wide spaces for barge navigation is very great on Western rivers. In the first place, the navigable depth of water is so little, that the surface of the submerged parts of the hull of the tug has but little hold upon the water compared to the large surface exposed to the wind, and is, therefore, more affected by the winds than vessels navigating deep water. The tugs and barges have flat bottoms and no keels, and slide easily sidewise. At shoal places the vessels barely float over the sand-bars, and this proximity also seriously affects the steering of the boat.

On account of shoals and winds, and sometimes on account of eddies and oblique currents, the vesel or tow can only be kept on the proper course by being held somewhat obliquely to it, thus occupying space more than the mere width. In towing, the object is placed well in front of the tow-boat, and rarely alongside, and where there is an odd number of barges towed, or other inequality which prevents equal parts being placed on each bow, this inequality is regulated by varying the obliquity.

In considering the passage of vessels with tows between piers or around bends of the channels, this arrangement must always be kept in view.

The barges are arranged three, four, five, or more abreast, and as many in number behind each other, firmly lashed together. Behind these the tug is placed, suitably attached. The sizes of these tows depends only upon the width and depths of the river channels where bridges do not interfere. Bridge openings should therefore be proportioned to the size of the river. As extreme cases, we have on the Lower Ohio and Mississippi coal-tows of as high a number as 32 barges, conveying 539,000 bushels of coal, and it is proposed to make up large grain barges into fleets at Saint Louis, carrying 100,000 bushels of grain and more. On the Upper Ohio the coal fleets are made smaller, the size depending upon the stage of the river. On the Upper Mississippi very large fleets of light-draught barges are practicable if it were not for the draw-bridges, as is shown by the large size of the rafts. It is not saying too much that the inland system of transportation practicable on the Mississippi and its tributaries furnishes a means of moving great quantities of coal, ores, grain, &c., unequaled in the world. The transportation by means of barges will undoubtedly increase, and no restriction to its development to the fullest extent should be allowed by bridges or anything else.

Rafting.—The raft interest, which is of the utmost importance to the country in supplying cheap lumber, is now carried on by steamboats in the same manner as the coal-fleet system, and with much greater economy than formerly, when manual force at long oars was relied upon to guide these cumbrous floating masses.

This business, too, requires wide spans, much greater than those provided by existing draw-bridges, and high enough to allow the steamboats to pass under and guide the raft through. Large Upper Mississippi rafts are about 270 feet wide and 450 feet long, and all such have now to be made so as to separate in two parts to pass the draw-bridges on the Upper Mississippi. (See, further, Report of Board of Engineers on Sheer-booms; Annual Report Chief of Engineers for 1877, p. 817; also appendix to this report contained in House Ex. Doc. No. 41, Forty-fourth Congress, second session.)

General remarks.—When the bridges across the Mississippi were authorized in 1866, the barge system of transportation had already made itself important there, and although the rafting by steam was not then practiced, the inapplicability of draw-bridges was seriously felt.

Railroads running in the direction of the river, however, were not yet developed, and passenger and mail transportation along it was of such great importance that some persons much interested in the navigation thought that draw-bridges with 150 feet clear openings were superior to high bridges which gave headway of only 50 feet at high-water.

The building of railroads has diminished the proportionate amount of passenger travel on the river, and increased the amount of bulky and heavy products and manufactures, and has already changed these relations.

The building of the bridge at Saint Louis, giving a headway of only 50 feet at ordinary extreme high-water, has compelled a change in the boats running above, so that they are now prepared to pass under any bridge without trouble or delay which gives the same clear height and has spans of 300 to 400 feet width in the clear for rafts and barges, so that one permanent high bridge without draw fixes a limit of height for all places above, and when a boat is built to pass under one she can without more trouble pass all such. On the contrary, each draw-bridge causes its own obstruction, and the total obstruction increases with the number, which is now so great and liable to cause such detention as to prevent all regularity in running a line of steamboats.

Experience on the Upper Mississippi has shown that the proper site for a bridge is where the channel is straight and next to the bank of both high and low water. The channel spans, whether low draw or high fixed ones, would then be next the bank, which at all times would furnish the best guide for the pilot; and then the further reason that the side next the shore can be protected by piling or other means that will allow the vessels to rub against it with safety; and this location also permits of auxiliary works being built out from the opposite shore to make the channel permanent.

Such locations cannot readily be made where the rise of the river from low to high water much exceeds 20 feet, because the necessary slope of the banks will require an open span between the margin of the low and high water shores. It is therefore not generally applicable to the Ohio, or Missouri, or to the Mississippi below the mouth of the Illinois River.

On none of the Western rivers has nature prepared such a channel of navigation as upon the Mississippi above the junction of the Missouri.

Its gentle slope and current, clear water, freedom from snags, limited range of height of floods, all render its navigation easy; and its condition is expressed to the eye of the traveler in its aspect of beauty. Its very gentleness has led to its being bridged with very trifling structures, which a turbulent stream like the Missouri would not suffer to stand. The latter has exacted much better bridge constructions on the average than those existing on the Upper Mississippi.

The navigation of the Upper Mississippi has a much more extensive interest than that represented by Saint Louis and the Upper Mississippi, considered by themselves. This navigation is but a part of a system which includes the whole Mississippi basin, the Ohio, the Missouri, the Illinois, &c. The vessels which navigate the Ohio should be allowed to carry their loads to Saint Paul as well as Saint Louis, and any structure which compels a change of character of vessel on the upper and lower sides of it, or a breaking of bulk, is simply an obstruction to navigation of the character of the rapids at Louisville, at Keokuk, and at Rock Island, which the government is spending large sums to remove.

In view of the probability that there will be before long a necessity for rebuilding some of the present draw-bridges at least, and substituting high ones, I have thought it proper to present the gauge data I have been enabled to get affecting the question of height of bridge when draw-spans are omitted, and discuss the question of headway under bridges. This has never been done, or even practicable until recently, for want of observations. This subject will form the remainder of this chapter.

Knowledge of varying stages important.—The surface of the water of the Mississippi is generally rising or falling, with occasional periods when it is stationary, and a knowledge of the annual average duration of these various stages is one of the important factors in considering the effect upon navigation of bridges of different heights at different places.

Gauge data used.—With the view to gain this knowledge we have obtained the most important *continious* gauge-readings along the river, from the earliest records, which were made during the period between 1860 and 1876.

This period does not include any very remarkable floods, such as those of 1828, 1851 and, 1858; but in some places it does the remarkable low-waters which occurred in 1863 and 1864.

In the following presentation and discussion, records of gauge-readings have been obtained and used in comparison—

At Saint Louis, from January 1, 1861, to December 31, 1876.
At Quincy, from January 1, 1869, to December 31, 1876.
At Rock Island, from January 1, 1861, to December 31, 1876.
At Clinton, from October 17, 1866 and 1867, while river was open.
At Dubuque, from May 1, 1869, to December 31, 1876.
At Prairie du Chien during 1867, '68, '69, while river was open.
At Winona, from October 4, 1866, part of 1867, and 1868.
At Saint Paul during 1867, '68, '69, while river was open.

The observations at Saint Louis are kept at the expense of that city, part of which were furnished us direct, part were derived from the report of the board of engineers on the Saint Louis bridge, and part through the assistance of Maj. C. J. Allen, United States Engineers, in General Simpson's office. Those at Quincy were obtained from Chicago, Burlington and Quincy Railroad Company, through Mr. W. Beckwith, superintendent of bridges. Those at Rock Island are from observations by the old bridge company up to 1869, and since then from observations made under direction of the engineer officers of the Army. Those at Dubuque were furnished by the bridge company, Hon. William B. Allison, president, through Mr. C. H. Booth, secretary.

All the foregoing named were obtained without expense to the survey. The others were made for the purposes of this investigation and at its expense.

The gauge-readings made at Keokuk might have been obtained, but its situation at the foot of the rapids destroys their general value, and the canal makes a bridge at this place a special one in charater, to be determined by the necessities of the canal navigation.

There were other gauge observations attainable besides those named, but were not useful in the general consideration of this subject.

Gauge observations at Saint Louis and Rock Island compared for period of 16 *years.*—The longer period of continued observations at Saint Louis and at Rock Island makes the averages deduced from them more reliable than at any other points, although the situation of both these places is peculiar.

At Saint Louis the Mississippi is immediately affected by its long tributary, the Missouri River, and at Rock Island by the rapids. These peculiarities are shown in Diagram H, in which the average readings of the gauges are taken for the period, 16 years, between January 1, 1861, and December 31, 1876.

The gauge-readings at Saint Louis are divided by 2, so as to bring the two curves nearer together on the diagram. This does not give an equality of rise and fall, and therefore they are placed with the midway point in common, so as to divide the excess about equally at the times of high water in April and May, and that of the low-waters in November and December. We might have made an exact equality of rise and fall by reduction, but this is near enough for this comparison. The peculiar differences show for themselves on the diagram. For instance, at Rock Island there is a rise in December, January, and February, not so marked at Saint Louis, which is probably due to the ice at Rock Island. With the spring rains there is a considerable uniformity of rise at the two places, but it reaches a greater relative height at Rock Island, and much sooner subsides.

As a matter of further interest, we have prepared Diagram I for this 16-year period for Saint Louis, and Diagram J for Rock Island, giving the mean curve and the year when the highest and lowest water occurred on any day of the year. These show the extreme ranges that have been observed at the same dates in these 16 years, and the included space forms what we have called a *zone* of river oscillations, which includes all our known observations. The three exceptional high-waters of 1844, '51, '58, recorded at Saint Louis, are noted on the diagram, but not included in the *zone*. We could not give each year's curve without too great confusion or resorting to colors which photolithography would not reproduce. These diagrams furnish interesting data for comparison and study, and information as to probability of high and low water at any time of the year, useful in planning engineering operations.

The daily observations are preserved in permanent records and can easily be procured when desired for any special purpose.

Comparison of means of gauge-readings at Saint Louis, Quincy, Rock Island, and Dubuque.—In order to see the effect of the natural conditions at Saint Louis and Rock Island, we have compared the simultaneous gauge observations for the period of 8 years (January 1, 1869, to December 31, 1876), at Quincy and Dubuque (normal parts of the river), with those at Saint Louis and Rock Island.

As in the preceding case, the Saint Louis gauge-readings have been simply divided by 2, and the midway point of all made common on the diagram (Diagram K). This diagram itself shows everything that can be described in words, and only a few points will be noted. First, we see that the stand of the gauge at Rock Island, near mid-height during the months of January and February, is anomalous and does not agree with places above and below it, and must be due to local ice gorgings, and that a great uniformity of relative conditions during these months exists at Dubuque, Quincy, and Saint Louis, and generally high-water and low-water exist at the same time all along the valley, which is a most useful condition for navigation. Second, we see that the high water in April and May occur at the uppermost place first and succeed in order of time regularly downward, showing that this is mainly what is locally known as a "head rise." Third, the June and July rise seems all the way to partake of the character of a head rise, re-enforcing a preceding local one and lengthening its period.

There is an exception in the case at Saint Louis, where an intermediate swell of water in excess appears to come from the Missouri.

The September rise occurs all along the valley at nearly the same time, and is consequently due to general rains throughout the region in this month.

One of the increasing advantages of the low-water navigation as we go lower down the river is shown by the curves in August and September, when there is so much business to do. The surface keeps comparatively up at Saint Louis much more than above.

We have added zone Diagram L for Quincy and zone Diagram M for Dubuque for the 8 years similar to those for Saint Louis and Rock Island for 16 years already described.

The gauge observations at other places which we have, do not furnish means for sufficient periods of time to be valuable as a zone diagram. They will, however, be considered further on in discussing the question of headway.

HEADWAY UNDER BRIDGES.

In order to consider the question of headway under bridges, we have arranged the data from gauge-readings into tables.

1. *Saint Louis tables, &c.*—At Saint Louis we take the number of days when the river in each month stood as follows: between zero (low water) and 5 feet, between 5 and 10 feet, and so on. This interval, 5 feet, was taken by the board of engineers on the Saint Louis bridge (see Annual Report of Chief of Engineers for 1874, pp. 645–648),* and we have followed it, because we could thus continue the same comparisons, and make available the data there given. That data embraces the period from 1861 to 1873, and we have added to it the data for the years 1874, '75, '76.

All these data are given in this report in *Table A*, year by year; the intervals of 5 feet are placed in the first left-hand column; the months at the heads of the columns, and the number of days in the body of the column. From it we see, for example, that in the month of January, 1861, there were 31 days when the river was between zero (low-water) and 5 feet above. In February, 1861, the river was 15 days between 5 and 10 feet above low-water, and 13 days between 10 and 15 feet above low-water, and so on for each month in each year.

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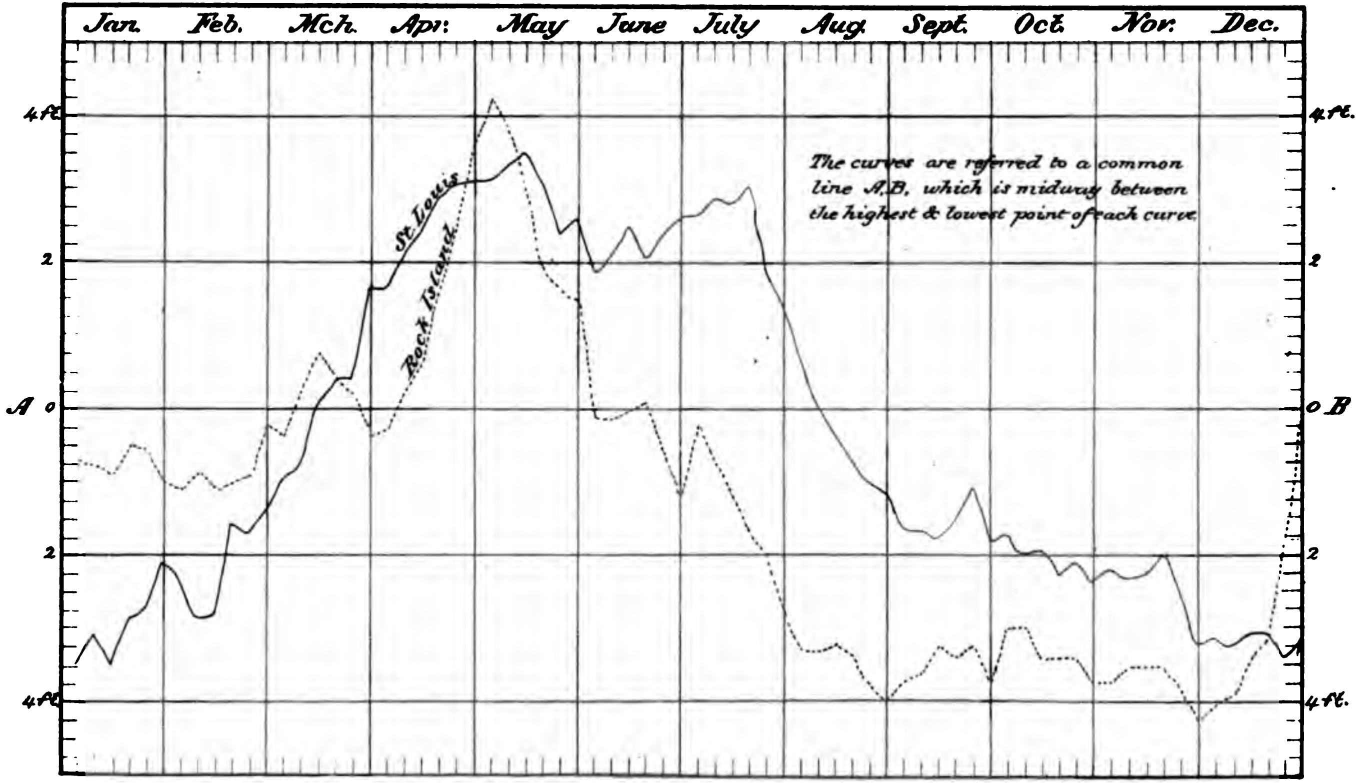
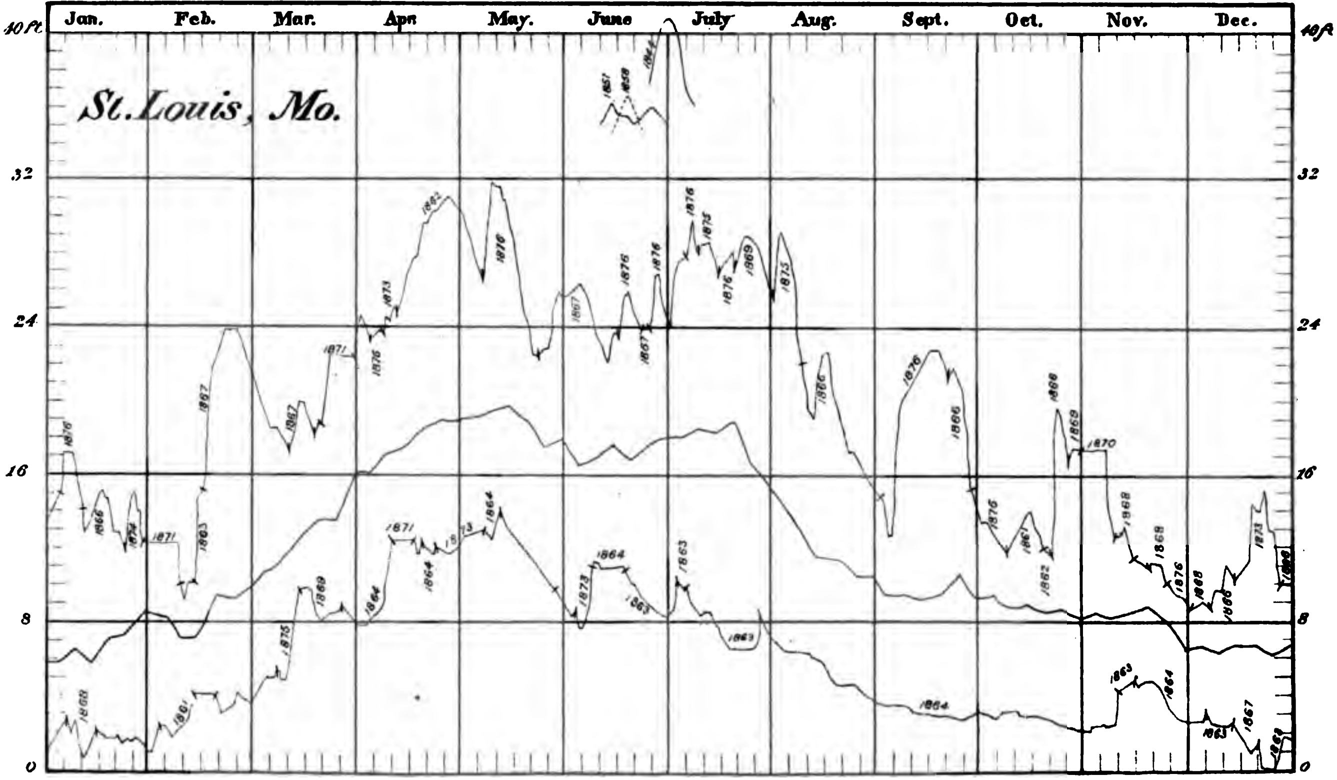
* The tables in the report of the board show the number of days the river was not below a given stage; but the consolidated Table H of the report does not show anything about the periods of headway under the bridge, and is therefore very misleading, owing to the errors in its construction.

Warren's Report Bridging Mississippi River. Diagram H.



AM. PHOTO-LITHO. CO. N.Y. (OSBORNE'S PROCESS)

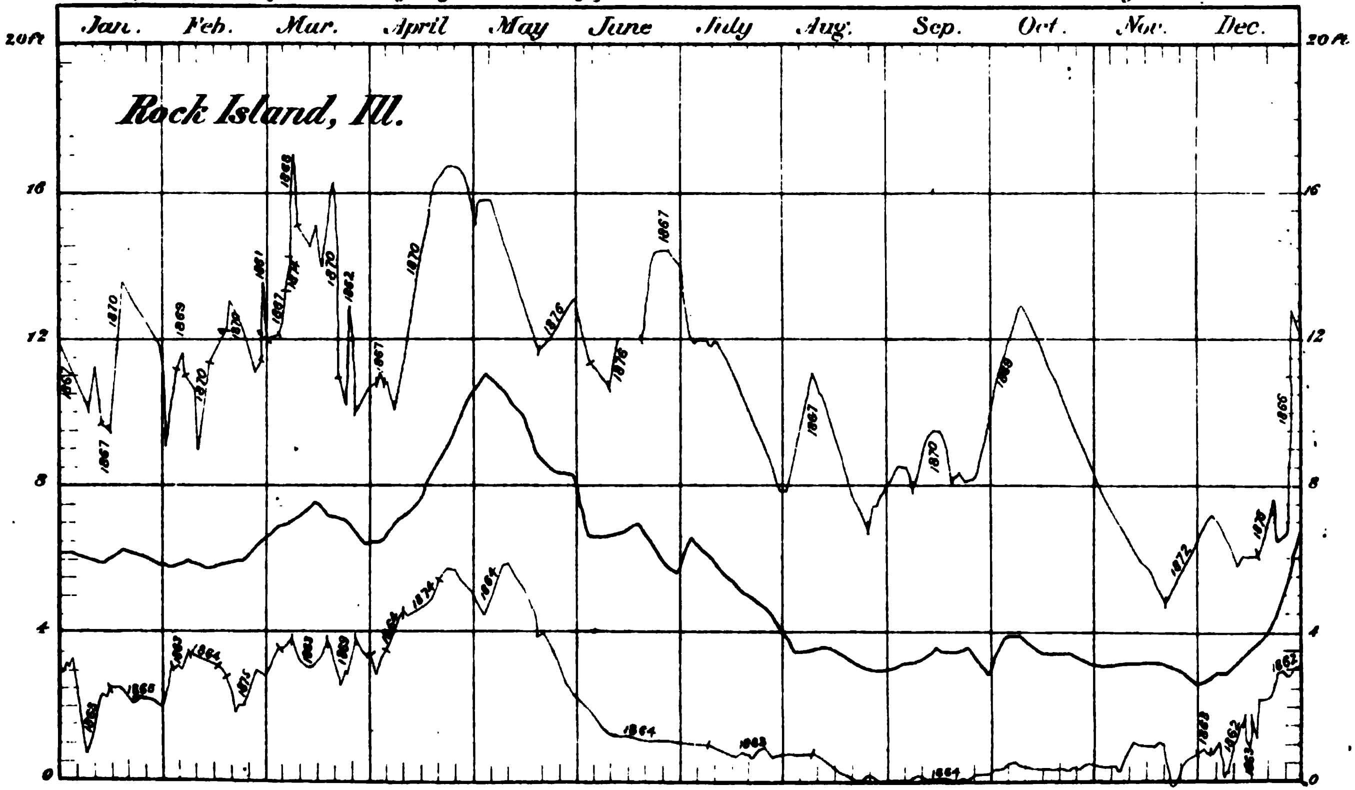
Warren's Report Bridging Mississippi River. *Diagram I.*



AM. PHOTO-LITHO. CO. N.Y. (OSBORNE'S PROCESS)

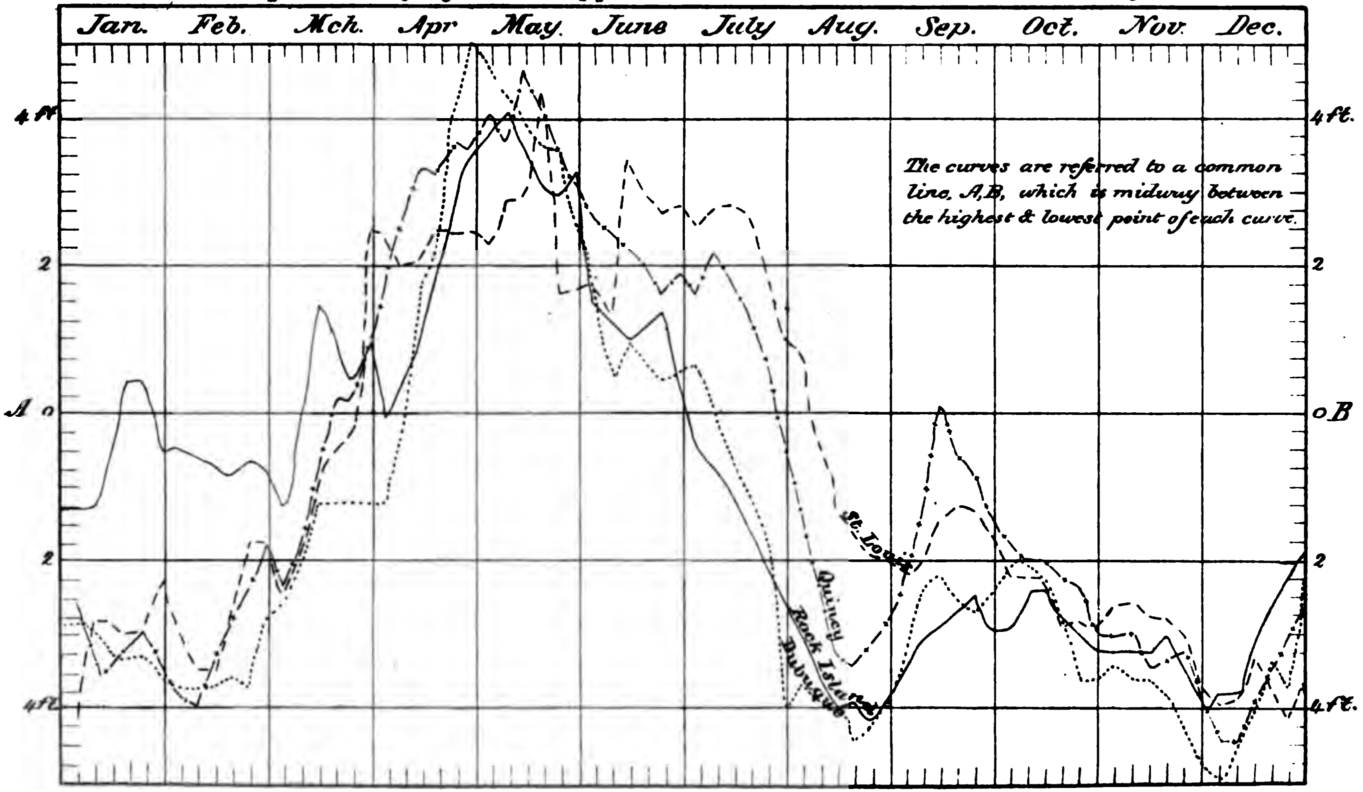
Warren's Report Bridging Mississippi River.

Diagram J.



AM. PHOTO-LITHO. CO. N.Y. (OSBORNE'S PROCESS)

Warren's Report Bridging Mississippi River. Diagram K.



The curves are referred to a common line, A,B, which is midway between the highest & lowest point of each curve.

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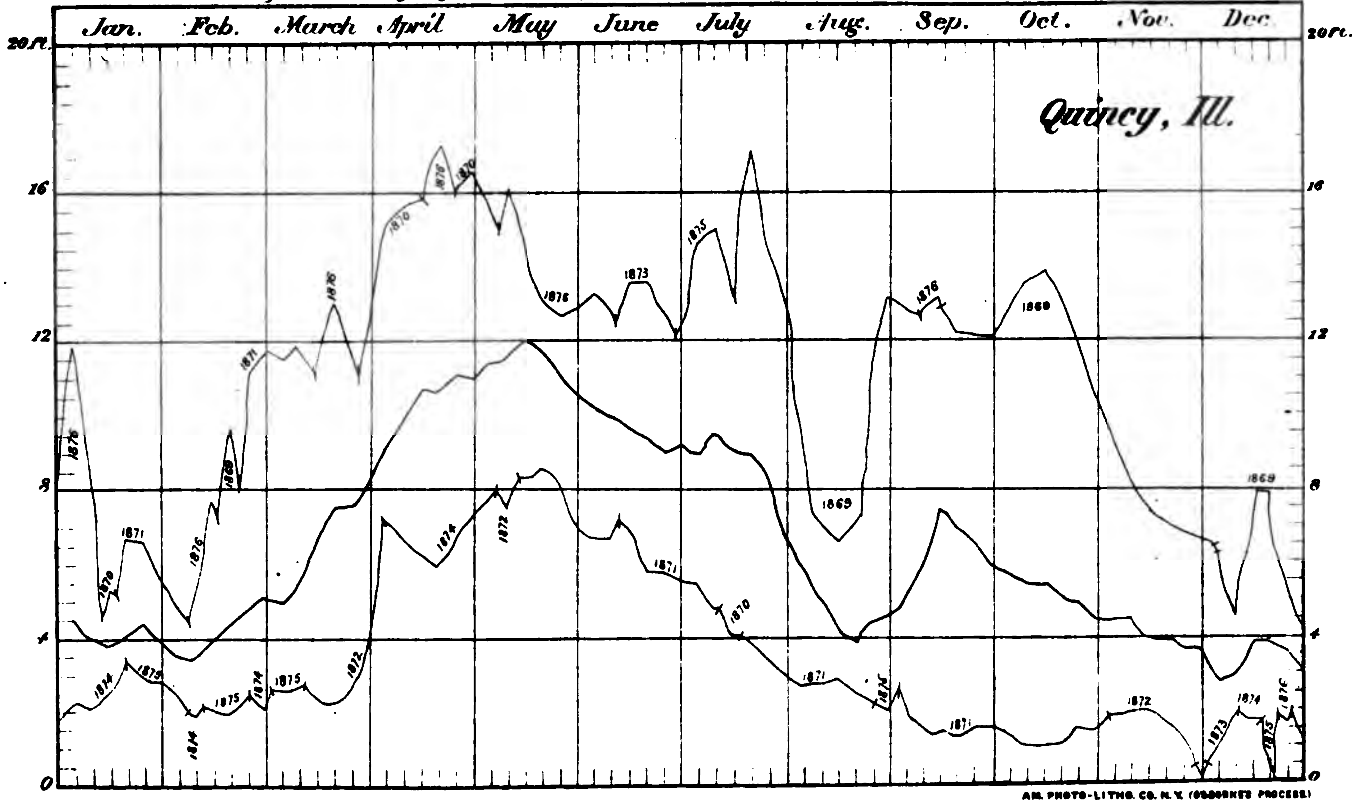
Warren's Report Bridging Mississippi River. Diagram L.



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Warren's Report Bridging Mississippi River.

Diagram M.

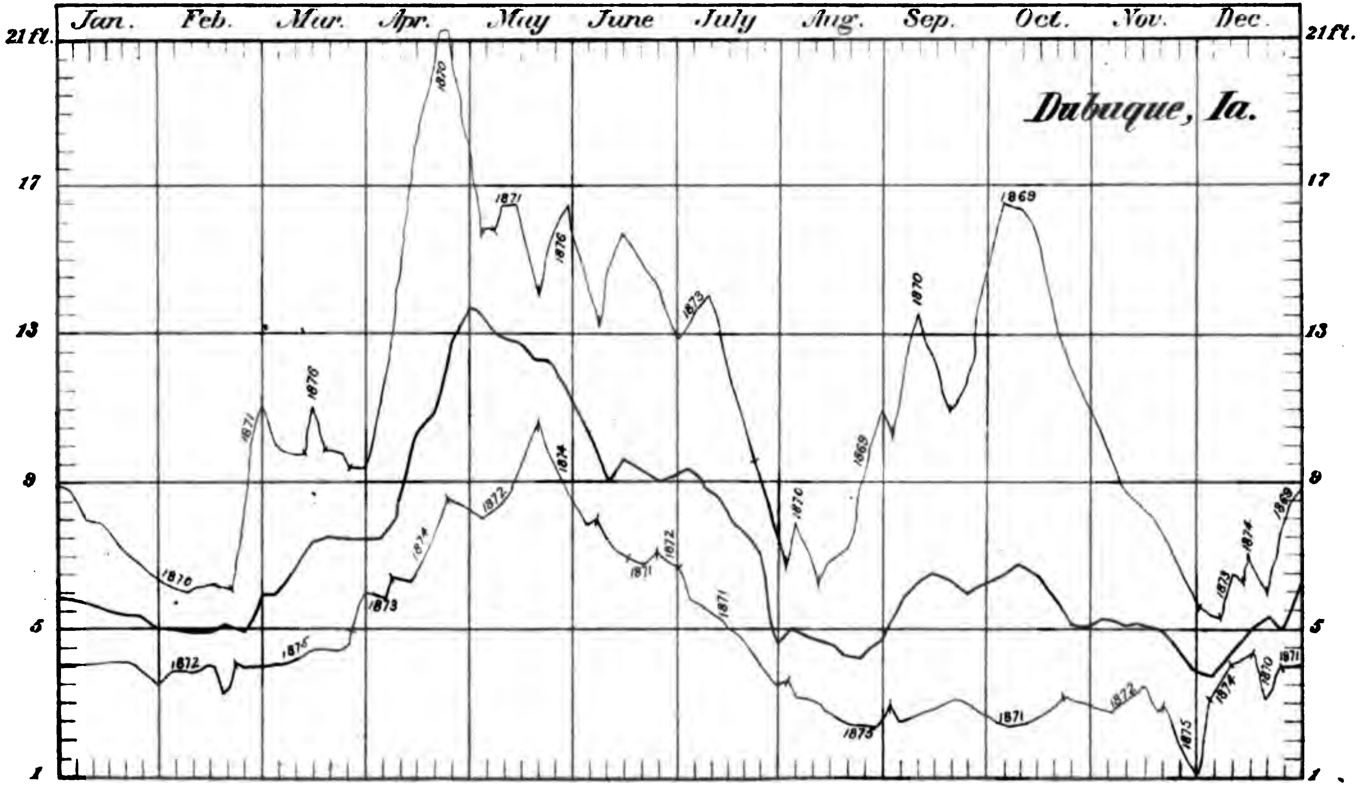

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TABLE A.—SAINT LOUIS.

1861.

Heights in feet.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Totals.
0– 5	31											7	38
5–10		15						22	4	15	30	24	110
10–15		13	4				8	9	26	16			76
15–20			27	19	18	30	18						112
20–25				11	10		5						26
25–30					3								3

1862.

Heights in feet.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Totals.
0– 5	7											3	10
5–10	16	27							4		28	24	99
10–15	8	1	18					28	26	31	2	4	118
15–20			13	2		20	19	3					57
20–25				9	19	10	12						50
25–30				10	11								21
30–35				9	1								10

1863.

Heights in feet.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Totals.
0– 5									7	31	18	31	87
5–10	6	8				12	25	29	23		12		115
10–15	23	7	11	19	31	18	6	2					117
15–20	2	13	20	11									46

1864.

Heights in feet.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Totals.
0– 5	8							12	30	31	23	12	116
5–10	23	29	21	9	2	6	7	19			7	19	142
10–15			10	15	16	24	24						89
15–20				6	13								19

1865.

Heights in feet.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Totals.
0– 5	31	12											43
5–10		13								5	12	28	58
10–15		2	12		9	19			24	26	18	3	113
15–20		1	18	17	21	11	22	14	6				110
20–25			1	12	1		5	15					34
25–30				1			4	2					7

1866.

Heights in feet.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Totals.
5–10	6	19								14	12	22	73
10–15	24	9	12	5			3	31	20	12	18	9	143
15–20	1		16	12	10	26	28		6	5			104
20–25			3	4	21	4			4				36
25–30				9									9

1867.

Heights in feet.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Totals.
0– 5	9											24	33
5–10	22	8							18	31	30	7	116
10–15		7	10	6				10	12				45
15–20		2	19	7	6			21					55
20–25		11	2	3	18	22	14						70
25–30				14	7	8	17						46
1868.													
0– 5	24	12	2									4	42
5–10	7	17	9					29	30	31	15	27	165
10–15			7	16		12	19	2			15		71
15–20			13	12	12	18	12						67
20–25				2	19								21
1869.													
5–10	11	7	14									16	48
10–15	20	17	17	6						2	30	15	107
15–20		4		23	30	9		23	27	29			145
20–25				1	1	21	1	6	3				33
25–30							30	2					32
1870.													
5–10	31	28	16				10	29	13	4	14	31	176
10–15			11			18	21	2	17	27	8		104
15–20			4		17	12					8		41
20–25				24	14								38
25–30				6									6
1871.													
0– 5	10								21	31	14	13	89
5–10	14	8					8	31	9		16	18	104
10–15	7	15		23	10	22	23						100
15–20		5	22	7	21	8							63
20–25			9										9
1872.													
0– 5	16									1	7	26	50
5–10	15	28	29					2	30	30	23	5	162
10–15		1	2	14	5			21					43
15–20				16	16	11	27	8					78
20–25					10	19	4						33
1873.													
0– 5											4	3	7
5–10	21	16	11					11	30	31	26	19	165
10–15	10	11	10	5				17				8	61
15–20		1	10	12	16		11	3				1	54
20–25				7	15	28	20						70
25–30				6		2							8

1874.

Heights in feet.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Totals.
0- 5	7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	25	32
5-10	16	16	4	.....	.....	.....	.....	28	28	31	30	6	159
10-15	8	12	12	15	26	15	31	3	2	.....	.....	.....	124
15-20	.....	.....	15	15	5	15	.....	.....	.....	.....	.....	.....	50

1875.

Heights in feet.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Totals.
0- 5	10	20	1	.....	.....	.....	.....	.....	.....	.....	1	16	48
5-10	21	8	22	.....	.....	.....	.....	.....	.....	17	29	15	112
10-15	.....	.....	8	3	.....	.....	.....	17	11	14	.....	.....	53
15-20	.....	.....	.....	25	18	19	.....	5	19	.....	.....	.....	86
20-25	.....	.....	.....	2	13	11	15	2	.....	.....	.....	.....	43
25-30	.....	.....	.....	.....	.....	.....	16	7	.....	.....	.....	.....	23

1876.

Heights in feet.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Totals.
0- 5	.....	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2
5-10	14	14	9	.....	.....	.....	.....	.....	.....	15	6	11	69
10-15	11	13	4	.....	.....	.....	.....	28	7	16	24	20	123
15-20	6	.....	12	.....	5	2	4	3	12	.....	.....	.....	44
20-25	.....	.....	6	15	7	22	9	.....	11	.....	.....	.....	70
25-30	.....	.....	.....	15	13	6	18	.....	.....	.....	.....	.....	52
30-35	.....	.....	.....	.....	6	.....	.....	.....	.....	.....	.....	.....	6

For convenience of comprehending and comparing the stages of the river for the same month in all the years observed, Table B is constructed from Table A. The heights are given in the left-hand column as in A, the years at the heads of the columns, and the number of days in the body of the table. The monthly averages of numbers of days are in the right-hand column. From this we see, for example, that although in January in 1861 and in 1865 the river was within 5 feet of low water all the month, there were 6 years out of 16 that it did not fall as low as 5 feet above low-water; that on the average it was but $9\frac{6}{10}$ days when the river was between 0 and 5 feet; that in these years the river was more than 20 feet above low-water in January, and only 3 of them where it was above 15 feet, and so on.

TABLE B.—SAINT LOUIS.

January.

	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	Average.
0- 5	31	7	6	8	31	....	9	24	....	....	10	16	....	7	10	....	9.7
5-10	....	16	6	23	....	6	22	7	11	31	14	15	21	16	21	14	13.9
10-15	....	8	23	....	....	21	....	....	20	....	7	....	10	8	....	11	6.7
15-20	....	....	2	....	....	4	....	....	....	....	....	....	....	....	....	6	0.7

February.

	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	Average.
0- 5	....	....	....	....	12	....	....	12	....	....	....	....	....	....	20	2	2.8
5-10	15	27	8	29	13	19	8	17	7	28	8	28	16	16	8	14	16.3
10-15	13	1	7	....	2	9	7	....	17	....	15	1	11	12	....	13	6.8
15-20	....	....	13	....	1	....	2	....	4	....	5	....	1	....	....	....	1.6
20-25	....	....	....	....	....	....	11	....	....	....	....	....	....	....	....	....	0.7

March.

	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	Average.
0– 5								2							1		0.2
5–10				21				9	14	16		29	11	4	22	9	8.4
10–15	4	18	11	10	12	12	10	7	17	11		2	10	12	8	14	9.3
15–20	27	13	20		18	16	19	13		4	22		10	15		12	11.8
20–25					1	3	2				9					6	1.3

April.

5–10				9													0.6
10–15			19	15		5	6	16	6		23	14	5	15	3		7.9
15–20	19	2	11	6	17	12	7	12	23		7	16	12	15	25		11.4
20–25	11	9			12	4	3	2	1	24			7		2	15	5.6
25–30		10			1	9	14			6			6			15	3.8
30–35		9															0.6

May.

5–10				2													0.1
10–15			31	16	9						10	5		26			6.1
15–20	18			13	21	10	6	12	30	17	21	16	16	5	18	5	13.0
20–25	10	19			1	21	18	19	1	14		10	15		13	7	9.2
25–30	3	11					7									13	2.1
30–35		1														6	0.4

June.

5–10			12	6													1.1
10–15			18	24	19			12		18	22			15			8.0
15–20	30	20			11	26		18	9	12	8	11		15	19	2	11.3
20–25		10				4	22		21			19	28		11	22	8.6
25–30							8						2			6	1.0

July.

5–10			25	7						10	8						3.1
10–15	8		6	24		3		19		21	23			31			8.4
15–20	18	19			22	28		12				27	11			4	8.8
20–25	5	12			5		14		1			4	20		15	9	5.3
25–30					4		17		30						16	18	5.3

August.

0– 5				12													0.7
5–10	22		29	19				29		29	31	2	11	28			12.5
10–15	9	28	2			31	10	2		2		21	17	3	17	28	10.6
15–20		3			14		21		23			8	3		5	3	5.0
20–25					15				6						2		1.5
25–30					2				2						7		0.7

September.

0– 5			7	30							21						3.6
5–10	4	4	23				18	30		13	9	30	30	28			11.8
10–15	26	26			24	20	12			17				2	11	7	9.1
15–20					6	6			27						19	12	4.4
20–25						4			3							11	1.1

October.

	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	Average.
0– 5			31	31							31	1					5.4
5–10	15				5	14	31	31		4		30	31	31	17	15	9.0
10–15	16	31			26	12			2	27					14	16	19.0
15–20						5			29								2.1

November.

	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	Average.
0– 5			18	23							14	7	4		1		4.2
5–10	30	28	12	7	12	12	30	15		14	16	23	26	30	29	6	18.1
10–15		2			18	18		15	30	8						24	7.2
15–20										8							0.5

December.

	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	Average.
0– 5	7	3	31	12			24	4			13	26	3	25	16		10.2
5–10	24	24		19	28	22	7	27	16	31	18	5.	19	6	15	11	17.0
10–15		4			3	9			15				8			20	3.7
15–20													1				0.1

This table and Table C, described and given below, enable us to consider and decide what season to choose to have the stage of water best suited to any engineering or navigation purposes.

To enable a ready comparison of all the *monthly averages* of numbers of days that the river was at any stage to be made, *Table C* has been constructed from the averages in Table B. The heights are here given at the heads of the columns and the average number of days in the body of the table.

TABLE C.—SAINT LOUIS.

Monthly averages for sixteen years, from 1861 *to* 1876, *inclusive, of number of days the river-surface at Saint Louis was at the height indicated by the figures at the heads of the columns.*

Months.	0 to 5 feet.	5 to 10 feet.	10 to 15 feet.	15 to 20 feet.	20 to 25 feet.	25 to 30 feet.	30 to 35 feet.
January	9.7	13.9	6.7	0.75			
February	2.8	16.3	6.8	1.6	0.7		
March	0.2	8.4	9.3	11.8	1.3		
April		0.6	7.9	11.4	5.6	3.8	0.6
May		0.1	6.1	13.0	9.2	2.1	0.4
June		1.1	8.0	11.3	8.6	1.0	
July		3.1	8.4	8.8	5.3	5.3	
August	0.7	12.5	10.6	5.0	1.5	0.7	
September	3.6	11.8	9.1	4.4	1.1		
October	5.9	14.0	9.0	2.1			
November	4.2	18.1	7.2	0.5			
December	10.2	17.1	3.7	0.1			
Yearly average	37.3	117.0	92.8	70.7	33.3	12.9	1.0

To compare each year with the others and with the averages of all the years, *Table D* is constructed from the "Totals" of the columns in *Table A*. The figures in the body of the table are number of days.

An examination of this table shows how often during the period given that the average was reached, and how often and how many days were above and below the average in different years.

TABLE D.—SAINT LOUIS.

Table, by years, of number of days the river-surface at Saint Louis, Mo., was at the heights indicated by the figures at the heads of the columns.

Years.	0 to 5 feet.	5 to 10 feet.	10 to 15 feet.	15 to 20 feet.	20 to 25 feet.	25 to 30 feet.	30 to 35 feet.
1861	38	110	76	112	26	3	....
1862	10	99	118	57	50	21	10
1863	87	115	117	46	....	....	....
1864	116	142	89	19	....	....	....
1865	43	58	113	110	34	7	....
1866	....	73	143	104	36	9	....
1867	33	116	45	55	70	46	....
1868	42	165	71	67	21	....	....
1869	....	48	107	145	33	32	....
1870	....	176	104	41	38	6	....
1871	89	104	100	63	9	....	....
1872	50	162	43	78	33	....	....
1873	7	165	61	54	70	8	....
1874	32	159	124	50	....	....	....
1875	48	112	53	86	43	23	....
1876	2	69	123	44	70	52	6
Yearly average	37.3	117.0	92.9	70.7	33.3	12.9	1.0

In order to present one general table and curve exhibiting the matter of headway generally, we get from Table D an average of the following:

	Between—						
	0 and 5 feet.	0 and 10 feet.	0 and 15 feet.	0 and 20 feet.	0 and 25 feet.	0 and 30 feet.	0 and 35 feet.
Number of days	37.3	154.3	247.3	317.9	351.2	364.1	365.1

From these data the curve in Diagram N is constructed, with the numbers of days as abscissas, and the numbers 5, 10, 15, &c., as ordinates.

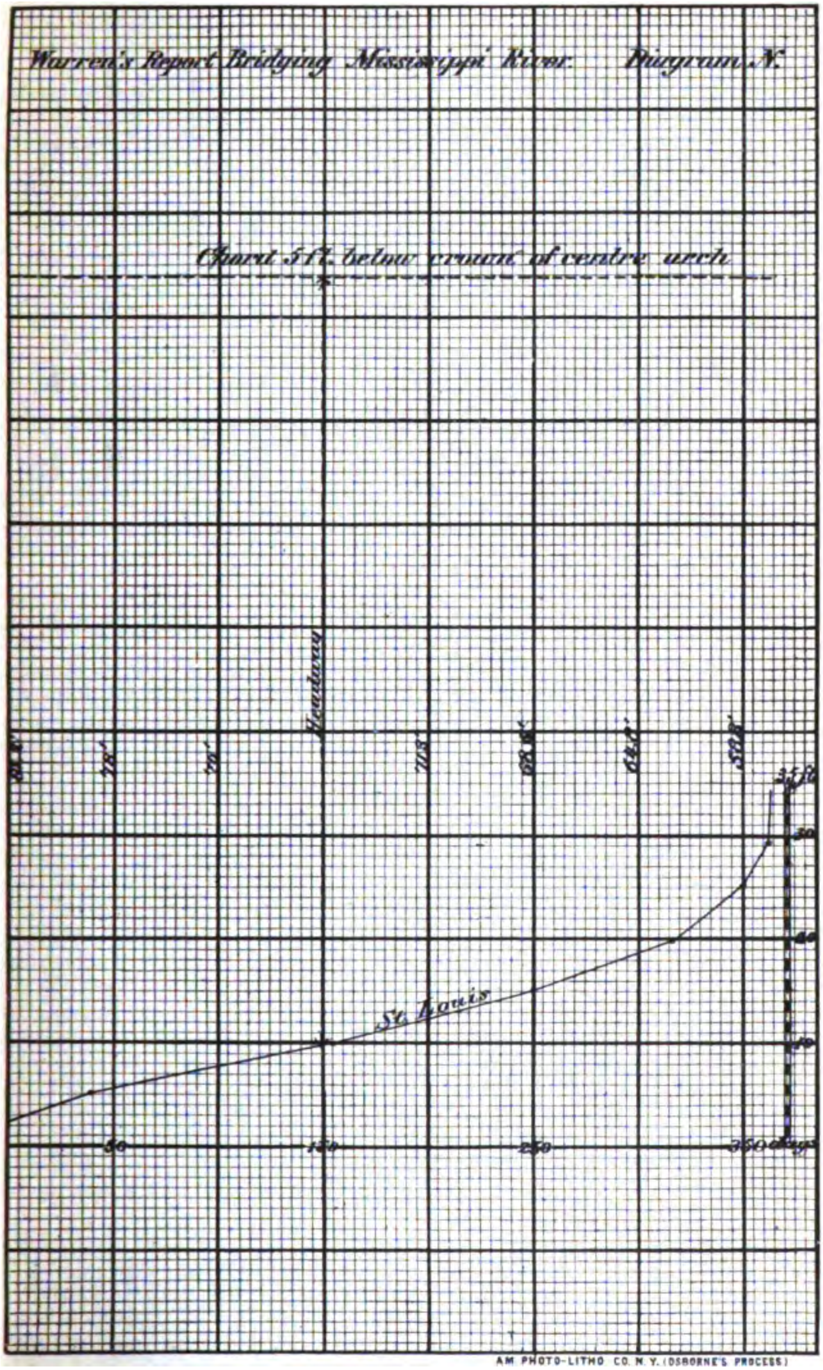
If, now, we take 50 feet above the city directrix at Saint Louis as the height of the lowest part of a bridge (the directrix being 33.8 above low water), we shall have the bridge represented on the diagram by the horizontal line 83.8 feet above zero. For convenience we have placed numbers giving the vertical heights from the bridge line downward on the right-hand side of the diagram. If we know the height of a vessel, this diagram will at once tell us the average number of days she cannot pass under it. Thus, if she required 75 feet headway, we see that there are only 125 days on the average when the river would not be too high. The months of the year when this height is most frequent are shown in *Table C.*

The many questions which may arise, it is believed, can all be as thoroughly considered as our knowledge of facts will permit by consulting and studying the foregoing tables and diagrams.

2. *Rock Island tables, &c.*—The tables of observations at this place are for comparison of conditions existing at Rock Island with those at Saint Louis as affecting high bridges.

We leave out the gauge observations for 1860, because they were not recorded at the latter place. The difference between extremes of rise and fall are about half at Rock Island of what they are at Saint Louis. We therefore make up our *tables* for intervals of only two feet instead of five. In this way the following tables, A, B, C, are constructed for Rock Island the same as for Saint Louis. And the same explanations, as to construction, &c., are applicable, and so we do not repeat them.

Warren's Report Bridging Mississippi River. Diagram N.



AM. PHOTO-LITHO. CO. N. Y. (OSBORNE'S PROCESS)

TABLE A.—ROCK ISLAND.

1861.

Heights in feet.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Totals.
0- 2								9	11			4	24
2- 4							11	22	19	7	30	22	111
4- 6			9	8		4	20			24		1	66
6- 8	13	23	13	5		4							58
8-10	14	5	4	3		9						3	38
10-12	4		2	4	20	13						1	44
12-14			3	4	9								16
14-16				6	2								8

1862.

0- 2											7	17	24
2- 4							4	31	30	6	23	14	108
4- 6						12	24			25			61
6- 8		16	17			6	3						42
8-10	31	12	8	10	5	6							72
10-12			5	11	7	6							29
12-14			1	9	6								16
14-16					13								13

1863.

0- 2	6					9	31	19	13	31	10	31	150
2- 4	25	7	11			10		12	14		20		99
4- 6		15	12	8	12	11			3				61
6- 8		6	8	19	11								44
8-10				3	8								11

1864.

0- 2						24	31	31	30	31	30	7	184
2- 4	31	24	15	8	11	6						9	104
4- 6			13	22	20							15	70
6- 8		2	3										5
8-10		3											3

1865.

0- 2												4	4
2- 4	31	18	5			23		6	9	26	15	8	141
4- 6		5	8		15	7	14	25	21	5	15	19	134
6- 8		2	3	12	4		17						38
8-10		1	11	8	6								26
10-12		2	4	10	6								22

1866.

0- 2										20			20
2- 4	10	26	1	4		6	23	15	30	11	30	21	177
4- 6	21	2	3	2	2	24	8	10				5	77
6- 8			6	4	6			6					22
8-10			6	14	3							1	24
10-12			7	4	4								15
12-14			8	2	8							4	22
14-16					8								8

1867.

Heights in feet.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Totals.
0– 2												5	5
2– 4									23	31	30	7	91
4– 6								3	7			5	15
6– 8	8	12	18	5			3	10				14	70
8–10	14	5	13	20	17	16	7	10					102
10–12	9	10		5	11	4	15	8					62
12–14		1			3	6	6						16
14–16						4							4
1868.													
0– 2							7	19	16				42
2– 4							18	12	14	31	9	12	96
4– 6					3	27	6				19	9	64
6– 8	31	29	17	26	15	3					2	8	131
8–10			10	4	13							2	29
10–12			1										1
12–14			2										2
14–16													
16–18			1										1
1869.													
0– 2													
2– 4		1	14									19	34
4– 6		11	16	2		11		19			17	12	88
6– 8	4	8	1	11	2	16	20	10	13		12		97
8–10	20	5		12	10	3	11	2	16	10	1		90
10–12	6	3		5	19				1	12			46
12–14	1									9			10
1870.													
0– 2												1	1
2– 4	2						19	19			4	20	64
4– 6	8					7	12	12	5	31	26	10	111
6– 8	7					12			12				31
8–10		6	3	4	19	11			13				56
10–12	3	16	15	8	5								47
12–14	11	6	4	4	4								29
14–16			5	5	3								13
16–18			4	9									13
1871.													
0– 2								7	29	26	6	1	69
2– 4	12						25	24	1	5	24	5	96
4– 6	13	8		8		18	6					25	78
6– 8	6	16	17	9	1	12							61
8–10		3	14	13	9								39
10–12					12								12
12–14		1			9								10
1872.													
0– 2									4	9	23		36
2– 4	13	25	5	3			3	30	26	22	5		132
4– 6	18	4	24	18	7	10	28	1			1	15	126
6– 8			1	9	13	15					1	16	55
8–10			1		11	5							17

1873.

Heights in feet.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Totals.
0- 2									22	5	9	7	43
2- 4								28	8	26	21	13	96
4- 6	31	28	16	4			5	3				6	93
6- 8			5	21	1	5	6					4	42
8-10			8	5	16	4	10					1	44
10-12			2		12	19	10						43
12-14					2	2							4

1874.

Heights in feet.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Totals.
0- 2								11				15	26
2- 4					1			19	24	8	19	16	87
4- 6		4	7	25		25	6	1	6	23	11		108
6- 8	7	24	14	5	24	5	25						104
8-10	23		1		6								30
10-12	1		4										5
12-14			3										3
14-16			2										2

1875.

Heights in feet.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Totals.
0- 2								25	5		9	11	50
2- 4	4	1	12				11	6	4	27	21	14	100
4- 6	7	27	16				7		8	4		4	73
6- 8	16		1			29	13		13			2	74
8-10	4		2	21	19	1							47
10-12				5	9								14
12-14				4	3								7

1876.

Heights in feet.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Totals.
0- 2	2	2											4
2- 4	20	16	7				5	31		26	30	5	140
4- 6	9	6	8	4			9		22	5		26	89
6- 8		5	7	3		5	3		8				31
8-10			9	5		16	11						41
10-12				3	16	4	3						26
12-14				15	15	5							35

TABLE B.—ROCK ISLAND.

January.

Heights in feet.	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	Average.
0- 2			6													2	0.5
2- 4			25	31	31	10				2	12	13			4	20	9.2
4- 6						21				8	13	18	31		7	9	6.7
6- 8	13						8	31	4	7	6			7	16		5.8
8-10	14	31					14		20					23	4		6.6
10-12	4						9		6	3				1			1.4
12-14									1	11							0.8

February.

Heights in feet.	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	Average.
0- 2																2	0.1
2- 4			7	24	18	26			1			25			1	16	7.4
4- 6			15		5	2			11		8	4	28	4	27	6	6.9
6- 8	23	16	6	2	2		12	29	8		16			24		5	8.9
8-10	5	12		3	1		5		5	6	3						2.5
10-12					2		10		3	16							1.9
12-14							1			6	1						0.5

March.

Heights in feet.	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	Average.
0– 2																	
2– 4			11	15	5	1			14			5			12	7	4.4
4– 6	9		12	13	8	3			16			24	16	7	16	8	8.2
6– 8	13	17	8	3	3	6	18	17	1		17	1	5	14	1	7	8.2
8–10	4	8			11	6	13	10		3	14	1	8	1	2	9	5.6
10–12	2	5			4	7		1		15			2	4			2.5
12–14	3	1				8		2		4				3			1.3
14–16										5				2			0.4
16–18								1		4							0.3

April.

Heights in feet.	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	Average.
0– 2																	
2– 4				8		4						3					0.9
4– 6	8		8	22		2			2		8	18	4	25		4	6.3
6– 8	5		19		12	4	5	26	11		9	9	21	5		3	8.1
8–10	3	10	3		8	14	20	4	12	4	13		5		21	5	7.6
10–12	4	11			10	4	5		5	8					5	3	3.4
12–14	4	9				2				4					4	15	2.4
14–16	6									5							0.7
16–18										9							0.6

May.

Heights in feet.	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	Average.
0– 2																	
2– 4				11										1			0.8
4– 6			12	20	15	2		3				7					3.7
6– 8			11		4	6		15	2		1	13	1	24			4.8
8–10		5	8		6	3	17	13	10	19	9	11	16	6	19		8.9
10–12	20	7			6	4	11		19	5	12		12		9	16	7.5
12–14	9	6				8	3			4	9		2		3	15	3.7
14–16	2	13				8				3							1.6

June.

Heights in feet.	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	Average.
0– 2			9	24													2.1
2– 4			10	6	23	6											2.8
4– 6	4	12	11		7	24		27	11	7	18	10		25			9.7
6– 8	4	6						3	16	12	12	15	5	5	29	5	7.0
8–10	9	6					16		3	11		5	4		1	16	4.4
10–12	13	6					4						19			4	2.9
12–14							6						2			5	0.8
14–16							4										0.3

July.

Heights in feet.	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	Average.
0– 2			31	31				7									4.3
2– 4	11	4				23		18		19	25	3			11	5	7.4
4– 6	20	24			14	8		6		12	6	28	5	6	7	9	9.1
6– 8		3			17		3		20				6	25	13	3	5.6
8–10							7		11				10			11	2.4
10–12							15						10			3	1.7
12–14							6										0.4

August.

Heights in feet.	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	Average.
0– 2	9		19	31				19			7			11	25		7.6
2– 4	22	31	12		6	15		12		19	24	30	28	19	6	31	16.0
4– 6					25	10	3		19	12		1	3	1			4.6
6– 8						6	10		10								1.6
8–10							10		2								0.8
10–12							8										0.5

September.

Heights in feet.	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	Average.
0- 2	11	....	13	30	....	....	....	16	....	....	29	4	22	....	5	....	8.1
2- 4	19	30	14	....	9	30	23	14	....	....	1	26	8	24	4	....	12.6
4- 6	....	....	3	....	21	....	7	....	....	5	....	....	....	6	8	22	4.5
6- 8	....	....	....	....	....	....	....	....	13	12	....	....	....	....	13	8	2.9
8-10	....	....	....	....	....	....	....	....	16	13	....	....	....	....	....	....	1.8
10-12	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	0.1

October.

Heights in feet.	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	Average.
0- 2	....	....	31	31	....	20	....	....	....	....	26	9	5	....		....	7.6
2- 4	7	6	....	....	26	11	31	31	....	....	5	22	26	8	27	26	14.1
4- 6	24	25	....	....	5	....	....	....	....	31	....	....	....	23	4	5	7.3
6- 8	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	......
8-10	....	....	....	....	....	....	....	....	10	....	....	....	....	....	....	....	0.6
10-12	....	....	....	....	....	....	....	....	12	....	....	....	....	....	....	....	0.8
12-14	....	....	....	....	....	....	....	....	9	....	....	....	....	....	....	....	0.6

November.

Heights in feet.	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	Average.
0- 2	....	7	10	30	....	....	....	....	....	....	6	23	9	....	9	....	5.9
2- 4	30	23	20	....	15	30	30	9	....	4	24	5	21	19	21	30	17.5
4- 6	....	....	....	....	15	....	....	19	17	26	....	1	....	11	....	....	5.6
6- 8	....	....	....	....	....	....	....	2	12	....	....	1	....	....	....	....	0.9
8-10	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	0.1

December.

Heights in feet.	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	Average.
0- 2	4	17	31	7	4	....	5	....	....	1	1	....	7	15	11	....	6.4
2- 4	22	14	....	9	8	21	7	12	19	20	5	....	13	16	14	5	11.6
4- 6	1	....	....	15	19	5	5	9	12	10	25	15	6	....	4	26	9.5
6- 8	....	....	....	....	....	....	14	8	....	....	....	16	4	....	2	....	2.7
8-10	3	....	....	....	....	1	....	2	....	....	....	....	1	....	....	....	0.4
10-12	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0.1
12-14	....	....	....	....	....	4	....	....	....	....	....	....	....	....	....	....	0.3

TABLE C.—ROCK ISLAND.

Monthly averages for 16 *years, from* 1861 *to* 1876, *inclusive, of number of days the river-surface at Rock Island, Ill., was at the height indicated by the figures at the head of the columns.*

	0 to 2 feet.	2 to 4 feet.	4 to 6 feet.	6 to 8 feet.	8 to 10 feet.	10 to 12 feet.	12 to 14 feet.	14 to 16 feet.	16 to 18 feet.
January	0.5	9.2	6.7	5.8	6.6	1.4	0.7	....	....
February	0.1	7.4	6.9	8.9	2.5	1.9	0.5	....	....
March	....	4.4	8.2	8.2	5.6	2.5	1.3	0.4	0.3
April	....	0.9	6.3	8.1	7.6	3.4	2.4	0.7	0.6
May	....	0.8	3.7	4.8	8.9	7.6	3.7	1.6	....
June	2.1	2.8	9.7	7.0	4.4	2.9	0.8	0.3	....
July	4.3	7.4	9.1	5.6	2.4	1.7	0.4	....	....
August	7.6	16.0	4.6	1.6	0.8	0.5	....	....	....
September	8.1	12.6	4.5	2.9	1.8	0.1	....	....	....
October	7.6	14.1	7.3	....	0.6	0.8	0.6	....	....
November	5.9	17.5	5.6	0.9	0.1	....	....	....	....
December	6.4	11,6	9.5	2.8	0.4	0.1	0.3	....	....
Yearly average	42.6	104.7	82.1	56.6	41.7	22.9	10.6	3.0	0.9

Comparison of conditions at Saint Louis with those at Rock Island, with regard to headway.—There are at least four months (December, January, February, and March) when the navigation above Rock Island is uncertain, if not impracticable, on account of ice. We must, therefore, in making the comparison for navigable headway, throw out the gauge observations at these two places for this wintry season. In this way we construct the following two tables of yearly means:

TABLE D.—SAINT LOUIS.

Table, by years, of number of days the river's surface at Saint Louis, Mo., was at the heights indicated by the figures at the head of the columns.

[The months of January, February, March, and December are left out.]

Years.	0 to 5 feet.	5 to 10 feet.	10 to 15 feet.	15 to 20 feet.	20 to 25 feet.	25 to 30 feet.	30 to 35 feet.
1861	....	71	59	85	26	3	....
1862	....	32	87	44	50	21	10
1863	56	101	76	11	....	....	....
1864	96	50	79	19	....	....	....
1865	....	17	96	91	33	7	....
1866	....	26	89	87	33	9	....
1867	....	79	28	34	57	46	....
1868	....	105	64	54	21	....	....
1869	....	....	38	141	33	32	....
1870	....	70	93	37	38	6	....
1871	66	64	78	36	....	....	....
1872	8	85	40	78	33	....	....
1873	4	98	22	42	70	8	....
1874	....	117	92	35	....	....	....
1875	1	46	45	86	43	23	....
1876	....	21	75	26	64	52	6
Average	14.4	61.4	66.3	56.6	31.3	12.9	1.0

TABLE D¹.—ROCK ISLAND.

Table, by years, of number of days the river's surface at Rock Island, Ill., was at the heights indicated by the figures at the head of the columns.

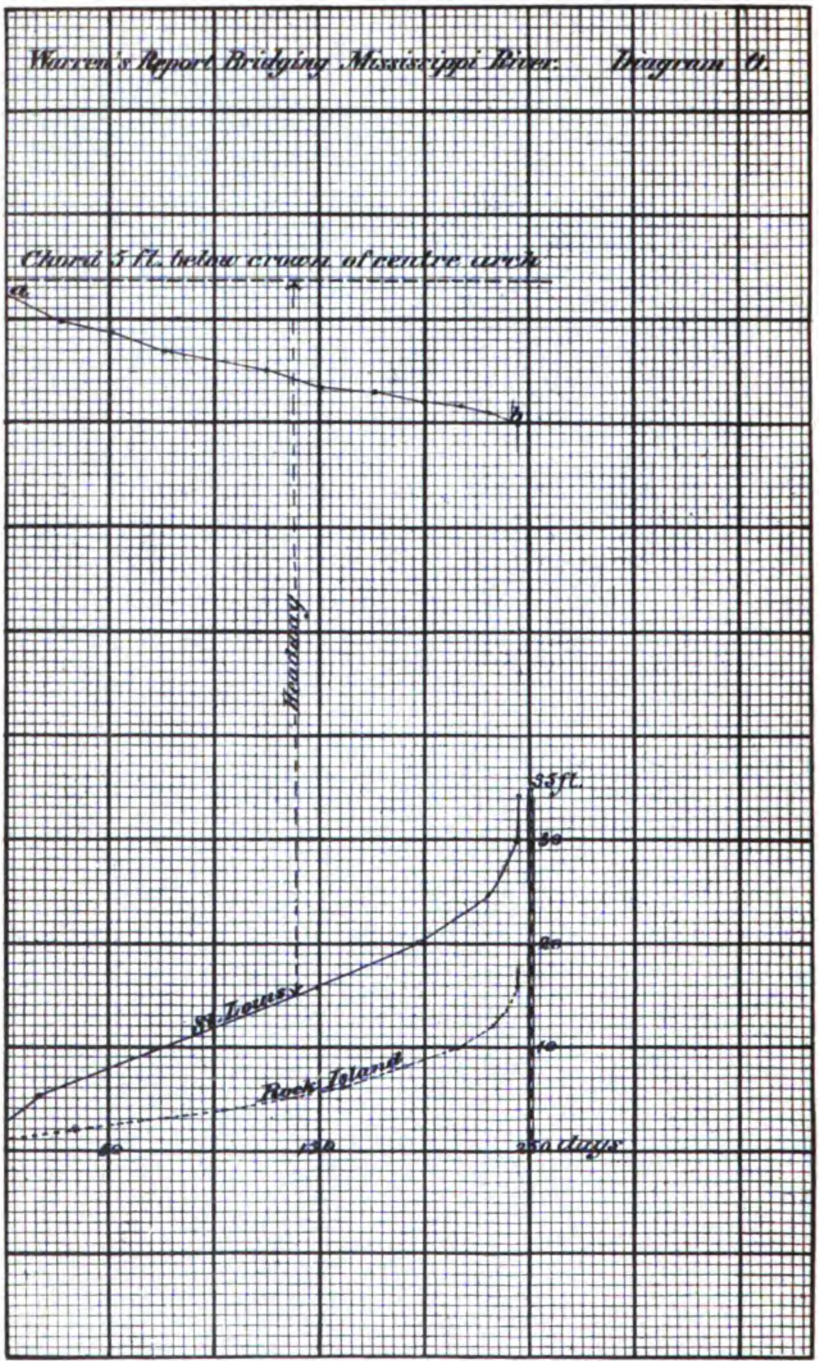
[The months of January, February, March, and December are left out.]

Years.	0 to 2 feet.	2 to 4 feet.	4 to 6 feet.	6 to 8 feet.	8 to 10 feet.	10 to 12 feet.	12 to 14 feet.	14 to 16 feet.	16 to 18 feet.
1861	20	89	56	9	12	37	13	8	....
1862	7	94	61	9	21	24	15	13	....
1863	113	56	34	30	11	....	....	....	....
1864	177	25	42	....	....	....	....	....	....
1865	....	79	102	33	14	16	....	....	....
1866	20	119	46	16	17	8	10	8	....
1867	....	84	10	18	70	43	15	4	....
1868	42	84	55	46	17	....	....	....	....
1869	....	....	49	84	65	37	9	....	....
1870	....	42	93	24	47	13	8	8	9
1871	68	79	32	22	22	12	9	....	....
1872	36	89	65	38	16	....	....	....	....
1873	36	83	12	33	35	41	4	....	....
1874	11	71	97	59	6	....	....	....	....
1875	39	69	19	55	41	14	7	....	....
1876	....	92	40	19	32	26	35	....	....
Average	35.6	72.2	50.8	30.9	26.6	16.8	7.8	2.6	0.6

From these tables we get the following:

For Saint Louis.

	0 to 5 feet.	0 to 10 feet.	0 to 15 feet.	0 to 20 feet.	0 to 25 feet.	0 to 30 feet.	0 to 35 feet.
Average number of days	14.4	75.8	142.1	198.7	230.0	242.9	243.9+



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For Rock Island.

	Between—								
	0 to 2 feet.	0 to 4 feet.	0 to 6 feet.	0 to 8 feet.	0 to 10 feet.	0 to 12 feet.	0 to 14 feet.	0 to 16 feet.	0 to 18 feet.
Average number of days...	35.6	107.8	158.6	189.5	216.1	232.9	240.7	243.3	243.9+

From these data we make Diagram O, which contains two curves, one for Saint Louis and one for Rock Island. These curves were constructed with the heights of the river's surface as ordinates, and the number of days it was at or below these heights as abscissas.

Upon this diagram we have drawn a horizontal line 83.8 feet above the zero of the heights, to represent the chord of the Saint Louis bridge, which is 5 feet below the crown of the middle arch. The space between this horizontal line and the Saint Louis curve shows the headway at that bridge.

To determine at what height a bridge at Rock Island would have to be placed to give the same headway, we have taken the height of this horizontal line at intervals of 25 days, and drawn a line, *a b*, through points at the same height above the Rock Island curve. The average height of this line *a b* above the zero (low-water) is the height at which a bridge at Rock Island must be built, to give as much headway as is given at Saint Louis. This, by calculation, is found to be about 75.5 feet, which may be seen by a mere inspection of the diagram. That is to say, that a bridge at Rock Island 75.5 feet above low water for half of the time (during high stages) would have from 0 to 7 feet more headway than the bridge at Saint Louis, and the other half (during low stages) the same amount less. Then, in order to secure an average headway as good as Saint Louis, it would have to be placed 75.5 feet above low-water, or 59.5 feet above high water.

If the Saint Louis bridge had been built 10 feet higher or lower, a bridge at Rock Island, to give equal average headway, would have to be the same amount higher or lower.

The foregoing discussion and deduction has value only in considering the relative obstruction that high bridges at these places would cause, if boats were compelled to lower their chimneys to pass them.

If boats are built so as to pass under a bridge with 50 feet headway, then bridges at any point need be built but 50 feet above high water.

3. *Quincy tables, &c.*—The gauge observations at this place are for eight years, from January 1, 1869, to December 31, 1876. The rise from low to high water is about 20 feet. The tables are made up with intervals of 2 feet

The following tables, A, B, C, are constructed for Quincy in the same manner as those for Saint Louis, previously described:

TABLE A.—QUINCY.

1869.

Heights in feet.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Totals.
0– 2													
2– 4	15	13	21										49
4– 6	16	1	10									15	42
6– 8		9		2		7		14			19	16	67
8–10		5		4		12		6			10		37
10–12				24	18	11	4	5		7	1		70
12–14					13		14	6	30	24			87
14–16							8						8
16–18							5						5

1870.

Heights in feet.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Totals.
0– 2												2	2
2– 4	3	19	3				6	15	2			19	67
4– 6	28	9	17				22	16	4	4	21	10	131
6– 8			2			11	3		10	25	8		59
8–10			3			17			14	2	1		37
10–12			3		15	2							20
12–14			3		6								9
14–16				22	6								28
16–18				8	4								12

1871.

Heights in feet.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Totals.
0– 2									25	30	7	5	67
2– 4	8	2					13	31	5	1	23	26	109
4– 6	14	19				12	18						63
6– 8	9	2		11		11							33
8–10		1	9	19	2	7							38
10–12		4	22		19								45
12–14					10								10

1872.

Heights in feet.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Totals.
0– 2			2							4	25	2	33
2– 4	31	27	25					14	19	27	5	19	167
4– 6		2	3				29	17	11			10	72
6– 8			1	15	5	8	2						31
8–10				15	16	9							40
10–12					10	8							18
12–14						5							5

1873.

Heights in feet.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Totals.
0– 2									14	7	7	14	42
2– 4	21	13	5					20	16	24	23	14	136
4– 6	10	13	4					10				3	40
6– 8		2	6	4			5	1					18
8–10			7	22	1		5						35
10–12			9	4	20	7	21						61
12–14					10	23							33

1874.

Heights in feet.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Totals.
0– 2	6	3										20	29
2– 4	16	25	3					25	18	4	13	11	115
4– 6	9		1	4			2	6	12	27	17		78
6– 8			2	25	11	26	29						93
8–10			25	1	20	4							50

TABLE A.—QUINCY—Continued.

1875.

Heights in feet.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Totals.
0- 2		4									6	11	21
2- 4	28	24	11					21	5	13	24	17	143
4- 6	3		12					6	2	11		3	37
6- 8			7			3	6	2	1	7			26
8-10			1	1	6	13	2	2	8				33
10-12				29	14	10	8		10				71
12-14					11	4	6		4				25
14-16							9						9

1876.

Heights in feet.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Totals.
0- 2												1	1
2- 4	8	9	1									17	35
4- 6	11	13	6				1	31	3	25	27	13	130
6- 8	3	7	1				4		6	6	3		30
8-10	3		8	2			4		8				25
10-12	4		7	9		19	7		5				51
12-14	2		8	2	19	11	6		6				54
14-16				7	12		9		2				30
16-18				10									10

TABLE B.—QUINCY.

January.

Heights in feet.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	Average.
0- 2						6			0.7
2- 4	15	3	8	31	21	16	28	8	16.3
4- 6	16	28	14		10	9	3	11	11.4
6- 8			9					3	1.5
8-10								3	0.4
10-12								4	0.5
12-14								2	0.2

February.

Heights in feet.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	Average.
0- 2						3	4		0.9
2- 4	13	19	2	27	13	25	24	9	16.5
4- 6	1	9	19	2	13			13	7.1
6- 8	9		2		2			7	2.5
8-10	5		1						0.7
10-12			4						0.5

March.

Heights in feet.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	Average.
0- 2				2					0.3
2- 4	21	3		25	5	3	11	1	8.6
4- 6	10	17		3	4	1	12	6	6.6
6- 8		2		1	6	2	7	1	2.4
8-10		3	9		7	25	1	8	6.6
10-12		3	22		9			7	5.1
12-14		3						8	1.4

April.

Heights in feet.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	Average.
0– 2									
2– 4									
4– 6						4			0.5
6– 8	2		11	15	4	25			7.1
8–10	4		19	15	22	1	1	2	8.0
10–12	24				4		29	9	8.3
12–14								2	0.3
14–16		22						7	3.6
16–18		8						10	2.3

May.

0– 2									
2– 4									
4– 6									
6– 8				5		11			2.0
8–10			2	16	1	20	6		5.6
10–12	18	15	19	10	20		14		12.0
12–14	13	6	10		10		11	19	8.6
14–16		6						12	2.2
16–18		4							0.5

June.

0– 2									
2– 4									
4– 6			12						1.5
6– 8	7	11	11	8		26	3		8.2
8–10	12	17	7	9		4	13		7.8
10–12	11	2		8	7		10	19	7.1
12–14				5	23		4	11	5.4

July.

0– 2									
2– 4		6	13						2.4
4– 6		22	18	29		2		1	9.0
6– 8		3		2	5	29	6	4	6.1
8–10					5		2	4	1.4
10–12	4				21		8	7	5.0
12–14	14						6	6	3.3
14–16	8						9	9	3.4
16–18	5								0.6

August.

0– 2									
2– 4		15	31	14	20	25	21		15.7
4– 6		16		17	10	6	6	31	10.7
6– 8	14				1		2		2.1
8–10	6						2		1.0
10–12	5								0.6
12–14	6								0.7

September.

0– 2			25		14				4.9
2– 4		2	5	19	16	18	5		8.1
4– 6		4		11		12	2	3	4.0
6– 8		10					1	6	2.1
8–10		14					8	8	3.8
10–12							10	5	1.9
12–14	30						4	6	5.0
14–16								2	0.3

October.

Heights in feet.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	Average.
0- 2	......	......	30	4	7	......	......	......	5.1
2- 4	......	......	1	27	24	4	13	......	8.6
4- 6	......	4	......	......	......	27	11	25	8.4
6- 8	......	25	......	......	......	......	7	6	4.8
8-10	......	2	......	......	......	......	......	......	0.2
10-12	7	......	......	......	......	......	......	......	0.9
12-14	24	......	......	......	......	......	......	......	3.0

November.

Heights in feet.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	Average.
0- 2	......	......	7	25	7	......	6	......	5.6
2- 4	......	......	23	5	23	13	24	......	11.0
4- 6	......	21	......	......	......	17	......	27	8.1
6- 8	19	8	......	......	......	......	......	3	3.8
8-10	10	1	......	......	......	......	......	......	1.4
10-12	1	......	......	......	......	......	......	......	0.1

December.

Heights in feet.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	Average.
0-2	......	2	5	2	14	20	11	1	6.9
2-4	......	19	26	19	14	11	17	17	15.4
4-6	15	10	......	10	3	......	3	13	6.8
6-8	16	......	......	......	......	......	......	......	2.0

TABLE C.—QUINCY.

Monthly averages for eight years, from 1869 *to* 1876, *inclusive, of number of days the river's surface at Quincy, Ill., was at the height indicated by the figures at the head of the columns.*

Months.	0 to 2 feet.	2 to 4 feet.	4 to 6 feet.	6 to 8 feet.	8 to 10 feet.	10 to 12 feet.	12 to 14 feet.	14 to 16 feet.	16 to 18 feet.
January	0.7	16.3	11.4	1.5	0.4	0.5	0.2	....	....
February	0.9	16.5	7.1	2.5	0.7	0.5	....	....	....
March	0.3	8.6	6.6	2.4	6.6	5.1	1.4	....	....
April	....	....	0.5	7.1	8.0	8.3	0.3	3.6	2.3
May	....	....	....	2.0	5.6	12.0	8.6	2.1	0.5
June	....	....	1.5	8.2	7.8	7.1	5.4	....	....
July	....	2.4	9.0	6.1	1.4	5.0	3.3	3.4	0.6
August	....	15.7	10.7	2.1	1.0	0.6	0.7	....	....
September	4.9	8.1	4.0	2.1	3.8	1.9	5.0	0.3	....
October	5.1	8.6	8.4	4.8	0.2	0.9	3.0	....	....
November	5.6	11.0	8.1	3.8	1.4	0.1	....	....	....
December	6.9	15.4	6.8	2.0	....	....	....	....	....
Yearly averages	24.4	102.6	74.1	44.6	36.9	42.0	27.9	9.4	3.4

Comparison of Saint Louis and Quincy with reference to headway.—The river at Quincy is generally free from ice nearly as late in the season as at Saint Louis. In comparing the gauge observations of the two places, we have therefore used them for the whole year.

To show the average number of days in a year that the river is at the different heights on the gauge, the two following tables have been prepared.

TABLE D″.—SAINT LOUIS.

Table, by years, of number of days the river's surface at Saint Louis, Mo., was at the heights indicated by the figures at the head of the columns.

Years.	0 to 5 feet.	5 to 10 feet.	10 to 15 feet.	15 to 20 feet.	20 to 25 feet.	25 to 30 feet.	30 to 35 feet.
1869	....	48	107	145	33	32	....
1870	....	176	104	41	38	6	....
1871	89	104	100	63	9	....	....
1872	50	162	43	78	33	....	....
1873	7	165	61	54	70	8	....
1874	32	159	124	50	....	....	....
1875	48	112	53	86	43	23	....
1876	2	69	123	44	70	52	6
Yearly averages	28.5	124.4	89.4	70.1	37.0	15.1	0.7

TABLE D″.—QUINCY.

Table, by years, of number of days the river's surface at Quincy, Ill., was at the heights indicated by the figures at the head of the columns.

Years.	0 to 2 feet.	2 to 4 feet.	4 to 6 feet.	6 to 8 feet.	8 to 10 feet.	10 to 12 feet.	12 to 14 feet.	14 to 16 feet.	16 to 18 feet.
1869	....	49	42	67	37	70	87	8	5
1870	2	67	131	59	37	20	9	28	12
1871	67	109	63	33	38	45	10	....	....
1872	33	167	72	31	40	18	5	....	....
1873	42	136	40	18	35	61	33	....	....
1874	29	115	78	93	50	....	....	....	....
1875	21	143	37	26	33	71	25	9	....
1876	1	35	130	30	25	51	54	30	10
Yearly averages	24.4	102.6	74.1	44.6	36.9	42.0	27.9	9.4	3.4

From these tables we get the following:

For Saint Louis.

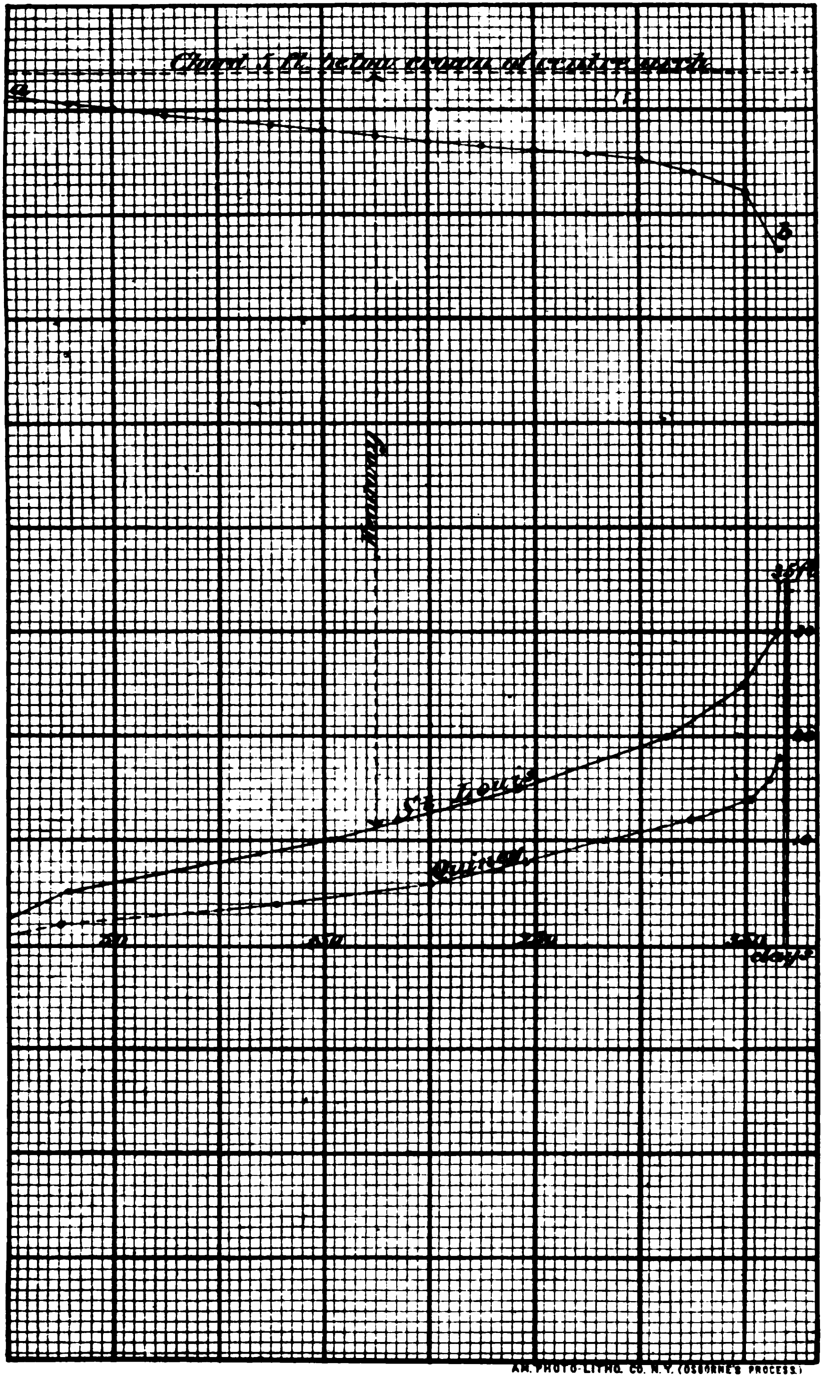
	From—						
	0 to 5 feet.	0 to 10 feet.	0 to 15 feet.	0 to 20 feet.	0 to 25 feet.	0 to 30 feet.	0 to 35 feet.
Number of days	28.5	152.9	242.3	312.4	349.4	364.5	365.2

For Quincy.

	From—								
	0 to 2 feet.	0 to 4 feet.	0 to 6 feet.	0 to 8 feet.	0 to 10 feet.	0 to 12 feet.	0 to 14 feet.	0 to 16 feet.	0 to 18 feet.
Number of days	24.4	127.0	201.1	245.7	282.6	324.6	352.5	361.9	365.3

From the data presented in these tables we construct Diagram P, which contains two curves, one for Saint Louis and one for Quincy, drawn in the same manner as those on diagram O, previously described.

Warren's Report Bridging Mississippi River. Diagram P.



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On this diagram (P) we have drawn a horizontal line, to represent a chord 5 feet below the crown of the center arch of the Saint Louis bridge; the space between this and the curve of the Saint Louis heights is the headway under the bridge at Saint Louis.

To determine the height of a bridge at Quincy, to give as much average headway as at Saint Louis, we have drawn a line, *a b*, at the same distance above the Quincy curve that the chord of five feet below the crown of the center arch of Saint Louis bridge is above the Saint Louis curve.

The average height of this line *a b* is about 77.2 feet above the zero (low-water); therefore a bridge at Quincy, to be as good for navigation as the Saint Louis bridge, would have to be placed 77.2 feet above low water, or 57 feet above high water. This would give more headway when the water was above the average, and less when below, than the Saint Louis bridge.

4. *Dubuque tables, &c.*—The gauge observations at this place are for eight years, from January 1, 1869, to December 31, 1876. The rise from low to extreme high water is about 22 feet; the tables are arranged for intervals of 2 feet rise.

The following tables, A, B, C, for Dubuque, Iowa, are constructed in the same manner as those for Saint Louis, Rock Island, and Quincy, previously described.

TABLE A.—DUBUQUE.

1869.

Heights in feet.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Totals.
0- 2													
2- 4												4	4
4- 6								6			2	19	27
6- 8						20	2	18			10	2	52
8-10					2	8	20	7	5		14	6	63
10-12					10	2	9		20	6	4		51
12-14					19				2	8			29
14-16									3	9			12
16-18										8			8

1870.

Heights in feet.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Totals.
0- 2													
2- 4								6				8	14
4- 6		3					17	11			9	23	63
6- 8	17	25	20			3	14	14			21		114
8-10	14		9	1		13			13	13			63
10-12			2	5	1	14			7	18			47
12-14				2	22				10				34
14-16				3	5								8
16-18				4	3								7
18-20				5									5
20-22				10									10

1871.

Heights in feet.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Totals.
0- 2											1		1
2- 4							6	25	30	31	29	14	135
4- 6	31	23					21	6				17	98
6- 8		2		5		18	4						29
8-10		1	27	7		8							43
10-12		2	4	5	6	4							21
12-14				13	7								20
14-16					10								10
16-18					8								8

1872.

Heights in feet.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Totals.
2– 4	6	11							25	24	30	7	103
4– 6	25	18	29	9				31	5	7		24	148
6– 8			2	11	2	10	30						55
8–10				10	16	13	1						40
10–12					8	7							15
12–14					5								5
14–16													
16–18													

1873.

0– 2													
2– 4	1	1						4	25	10	9		50
4– 6	30	27	6					24	5	21	21	17	151
6– 8			2	15			5	3				14	39
8–10			23	6	4	2	6						41
10–12				4	12	3	4						23
12–14				5	8	9	12						34
14–16					7	16	4						27
16–18													

1874.

0– 2												2	2
2– 4								19	1		3	8	31
4– 6	31	28	9				1	12	24	9	12	4	130
6– 8			16	23		19	5		5	22	15	17	122
8–10			6	6	6	11	18						47
10–12				1	23		7						31
12–14					2								2
14–16													
16–18													
18–20													

1875.

0– 2											6		6
2– 4		2					1	31	3	13	7	6	63
4– 6	31	26	26				13		4	16	17	23	156
6– 8			2				6		9	2		2	21
8–10			3	8		8	6		14				39
10–12				9	5	22	5						41
12–14				6	21								27
14–16				3	5								8
16–18				4									4

1876.

0– 2													
2– 4	1	13									1	5	20
4– 6	20	16	11				12	30	8	31	29	26	183
6– 8	10		7	5			7		22				51
8–10			5	3		5	4	1					18
10–12			8	4		14	7						33
12–14				1	8	6	1						16
14–16				17	17	5							39
16–18					6								6
18–20													

TABLE B.—DUBUQUE.

January.

Heights in feet.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	Average.
0- 2									
2- 4				6	1			1	1.0
4- 6			31	25	30	31	31	29	24.0
6- 8		17						10	4.0
8-10		14							2.0

February.

0- 2									
2- 4				11	1		2	13	3.8
4- 6		3	23	18	27	28	26	16	20.1
6- 8		25	2						3.9
8-10			1						0.1
10-12			2						0.3

March.

0- 2									
2- 4									
4- 6				29	6	9	26	11	11.6
6- 8		20		2	2	16	2	7	7.0
8-10		9	27		23	6	3	5	10.4
10-12		2	4					8	2.0

April.

0- 2									
2- 4									
4- 6				9					1.1
6- 8			5	11	15	23		5	8.4
8-10		1	7	10	6	6	8	3	5.8
10-12	8	5	5		4	1	9	4	4.0
12-14	8	2	13		5		6	1	3.8
14-16	3	3					3	17	3.3
16-18		4					4		1.1
18-20		5							0.7
20-22		10							1.4

May.

0- 2									
2- 4									
4- 6									
6- 8				2					0.2
8-10	2			16	4	6			3.5
10-12	10	1	6	8	12	23	5		8.1
12-14	19	22	7	5	8	2	21	8	11.5
14-16		5	10		7		5	17	5.5
16-18		3	8					6	2.1

June.

0- 2									
2- 4									
4- 6									
6- 8	20	3	18	10		19			8.7
8-10	8	13	8	13	2	11	8	5	8.5
10-12	2	14	4	7	3		22	14	8.3
12-14					9			6	1.9
14-16					16			5	2.6

July.

Heights in feet.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	Average.
0– 2									
2– 4			6				1		0.9
4– 6		17	21			1	13	12	8.0
6– 8	2	14	4	30	5	5	6	7	9.1
8–10	20			1	6	18	6	4	6.9
10–12	9				4	7	5	7	4.0
12–14					12			1	1.6
14–16					4				0.5

August.

0– 2									
2– 4		6	25		4	19	31		10.6
4– 6	6	11	6	31	24	12		30	15.0
6– 8	18	14			3				4.4
8–10	7							1	1.0

September.

0– 2									
2– 4			30	25	25	1	3		10.5
4– 6				5	5	24	4	8	5.7
6– 8						5	9	22	4.5
8–10	5	13					14		4.0
10–12	20	7							3.4
12–14	2	10							1.5
14–16	3								0.4

October.

0– 2									
2– 4			31	24	10		13		9.8
4– 6				7	21	9	16	31	10.5
6– 8						22	2		3.0
8–10		13							1.6
10–12	6	18							3.0
12–14	8								1.0
14–16	9								1.1
16–18	8								1.0

November.

0– 2			1				6		0.9
2– 4			29	30	9	8	7	1	9.8
4– 6	2	9			21	12	17	29	11.2
6– 8	10	21				15			5.8
8–10	14								1.8
10–12	4								0.5

December.

0– 2						2			0.2
2– 4	4	8	14	7		8	6	5	6.5
4– 6	19	23	17	24	17	4	23	26	19.1
6– 8	2				14	17	2		4.4
8–10	6								0.8

TABLE C.—DUBUQUE.

Monthly averages for eight years, from 1869 to 1876, inclusive, of number of days the river's surface at Dubuque, Iowa, was at the height indicated by the figures at the head of the columns.

Months.	0 to 2 feet.	2 to 4 feet.	4 to 6 feet.	6 to 8 feet.	8 to 10 feet.	10 to 12 feet.	12 to 14 feet.	14 to 16 feet.	16 to 18 feet.	18 to 20 feet.	20 to 22 feet.
January		1.0	24.0	4.0	2.0						
February		3.8	20.1	3.9	0.1	0.3					
March			11.6	7.0	10.4	2.0					
April			1.0	8.4	5.2	4.7	4.6	3.5	1.0	0.6	1.2
May				0.2	3.5	8.1	11.5	5.5	2.1		
June				8.7	8.5	8.2	1.9	2.6			
July		0.9	8.0	9.1	6.9	4.0	1.6	0.5			
August		10.6	15.0	4.4	1.0						
September		10.5	5.7	4.5	4.0	3.4	1.5	0.4			
October		9.8	10.5	3.0	1.6	3.0	1.0	1.1	1.0		
November	0.9	9.8	11.2	5.8	1.8	0.5					
December	0.2	6.5	19.1	4.4	0.8						
Yearly averages	1.1	52.9	126.2	63.4	45.8	34.2	22.1	13.6	4.1	0.6	1.2

For the months of January, February, March, and April the averages are for seven years, no gauge being kept for these months in 1869.

Comparison of Saint Louis and Dubuque with reference to headway.—The river at Dubuque is generally closed by ice from December 1 to April 1; we have therefore left out this period in the tables that follow.

These tables show the average number of days in the eight months, from April 1 to December 1, that the river's surface was at the different heights noted at the head of the columns.

TABLE D'''.—SAINT LOUIS.

Table, by years, of numbers of days the river's surface at Saint Louis, Mo., was at the heights indicated by the figures at the heads of the columns.

[The months of January, February, March, and December left out.]

Years.	0 to 5 feet.	5 to 10 feet.	10 to 15 feet.	15 to 20 feet.	20 to 25 feet.	25 to 30 feet.	30 to 35 feet.
1869			38	141	33	32	
1870		70	93	37	38	6	
1871	66	64	78	36			
1872	8	85	40	78	33		
1873	4	98	22	42	70	8	
1874		117	92	35			
1875	1	46	45	86	43	23	
1876		21	75	26	64	52	6
Average number of days	11.3	71.6	63.6	48.6	35.4	12.7	0.8

The year 1869 is not included in getting the average.

TABLE D'''.—DUBUQUE.

Table, by years, of number of days the river's surface at Dubuque, Iowa, was at the heights indicated by the figures at the heads of the columns.

[The months of January, February, March, and December are left out.]

Years.	Feet.										
	0 to 2.	2 to 4.	4 to 6.	6 to 8.	8 to 10.	10 to 12.	12 to 14.	14 to 16.	16 to 18.	18 to 20.	20 to 22.
1869	......	8	50	57	51	29	12	8	......	......	......
1870	......	6	37	52	40	45	34	8	7	5	10
1871	1	121	27	27	15	15	20	10	8	......	......
1872	......	79	52	53	40	15	5	......	......	......	......
1873	......	48	71	23	18	23	34	27	......	......	......
1874	......	23	58	89	41	31	2	......	......	......	......
1875	6	55	50	17	36	41	27	8	4	......	......
1876	......	1	110	34	13	25	16	39	6	......	......
Average	1.0	47.6	57.8	42.1	29.0	27.9	17.7	13.1	3.6	0.7	1.4

The average is for seven years, the observations not commencing until May 1, 1869; that year is not included.

From these tables we get the following:

For Saint Louis.

	From 0 to—						
	5 feet.	10 feet.	15 feet.	20 feet.	25 feet.	30 feet.	35 feet.
Number of days	11.3	82.9	146.5	195.1	230.5	243.2	244

For Dubuque.

	From 0 to—										
	2 feet.	4 feet.	6 feet.	8 feet.	10 feet.	12 feet.	14 feet.	16 feet.	18 feet.	20 feet.	22 feet.
No. of days	1.0	48.6	106.4	148.5	177.5	205.4	225.1	238.2	241.8	242.5	244

From the data contained in these tables we construct Diagram Q, which contains two curves, one for Saint Louis and one for Dubuque. These are constructed in the same manner as those for Saint Louis and Rock Island, &c. The averages are for but 7 years, and for eight months in the year, leaving out the winter months of December, January, February, and March.

The line *a b* on this diagram is drawn at the same height above the Dubuque curve as the horizontal line, representing a chord 5 feet below the crown of the center arch of the Saint Louis bridge.

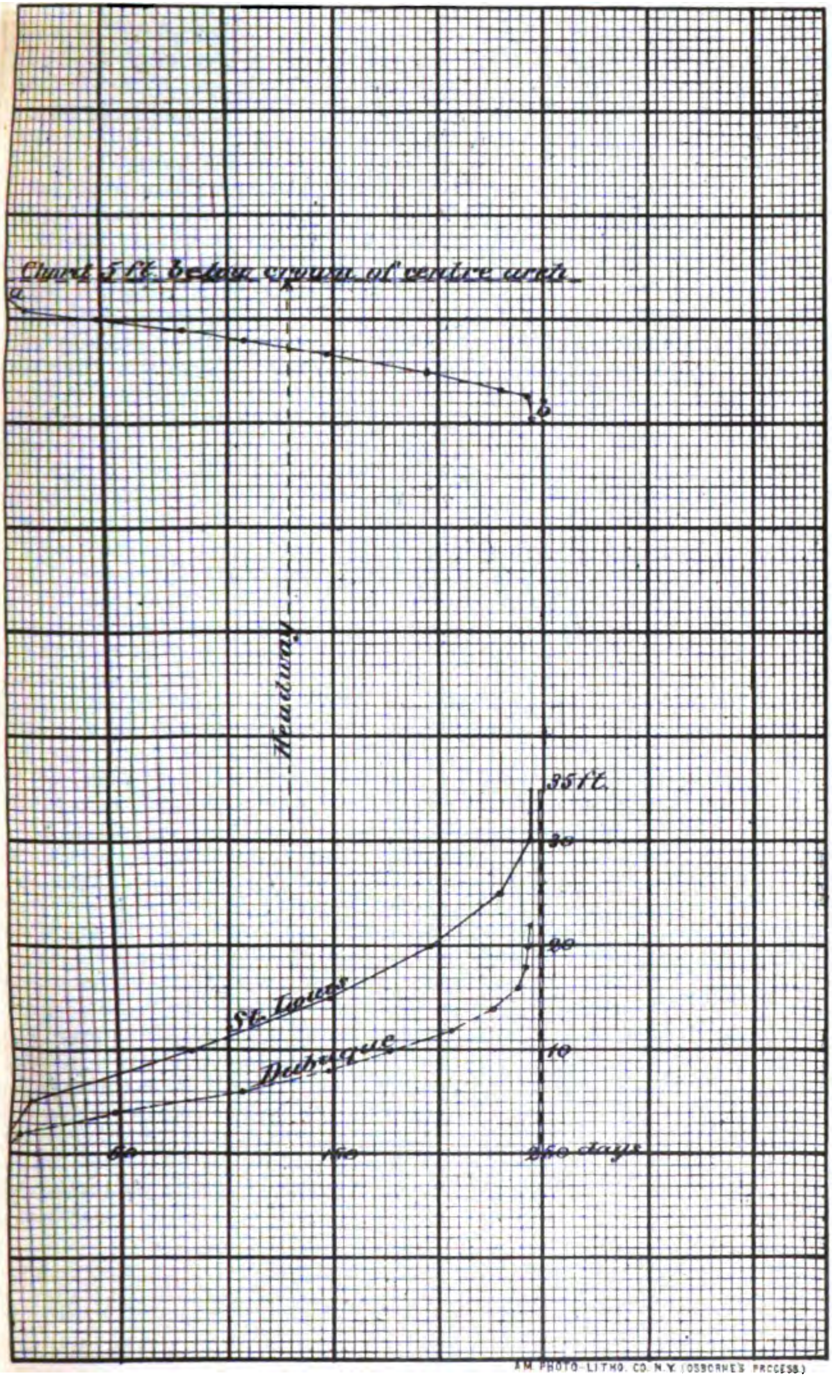
The average height of this line is 77.5 feet above the zero (low water).

This, then, is the height of a bridge at this place, that would give as good average headway as the Saint Louis bridge.

The rise from low to high water is 22 feet; the bridge would therefore have to be 55.5 feet above high-water.

5. *Other places on the Mississippi where gauge-observations have been made.*—These are enumerated in the first part of this chapter. At none

Warren's Report Bridging Mississippi River. Diagram Q.



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of these is the period observed greater than three years and only for seasons of navigation. The deductions from a mean of these would not have the weight of those already discussed. We have thought it sufficient, therefore, to give diagrams of the gauge-observations themselves at those places, each by itself (see Diagrams S, T, U, V), and with them Diagram R of the gauge-readings for the three corresponding years and seasons at Rock Island for comparison.

The examination of Diagram K has shown that there is much similarity between the means of eight years at Rock Island and Dubuque, omitting the winter months, and this similarity to Rock Island is shown as far as they can affect this question by the diagrams at Clinton, Prairie du Chien, Winona, and Saint Paul. It seems fair to conclude that the corresponding means, if we had the whole eight years' observations at these places, would present a result in regard to required headway not materially different from that at Quincy, Rock Island, and Dubuque. In other words, the bridges along the Upper Mississippi, to provide the same average headway as the present bridge at Saint Louis, should be about 77 feet above low water. This remark may be taken to include Burlington and other places where we have no gauge-observations, until we get so far below the Louisiana bridge as to encounter the effect of back-water from the Missouri River.

This point is not yet determined, and it would be only a safe precaution to cause all continuous bridges below the Louisiana bridge to give a clear headway at least 55 feet above high-water. The range of the Upper Mississippi between low and high water from the Louisiana bridge upward, as far as is known, nowhere exceeds that at Dubuque—namely, 22 feet.

An exception to the above general remarks as to requirements of headway above low-water may be made to the broad portion of the valley from a point about ten miles below La Crosse, and extending up to the head of Lake Pepin, where a height 74 or 75 feet above low-water would give the equivalent headway to the Saint Louis bridge.

As has been said before, this treatment of the question of relative practicable headway is made under the idea that vessels having different heights of chimneys and pilot-houses are to navigate the river, and then the required heights above low water are intended to make them all equal in their effect, so that a vessel that could pass under one could generally pass under all. But if the boats are all reduced to one fixed height of pilot-house or chimney, then the only requirement is that the bridges shall all be an equal height above high-water.

General rule for equating headway at places having different ranges from high to low water.—An examination of the preceding discussion of relative headway at Saint Louis, Quincy, Rock Island, and Dubuque, where the observations extend over long periods (and which leaves out extraordinary floods), shows the probable existence of a law, that the equivalent headway in all cases will be secured by establishing a fixed height, not above low-water or high-water, but above the midway height.

Place.	Range from low to high water.	Half range.	Height above high-water.	Height above low-water.	Height above mid range.
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Saint Louis	35	17.5	50.0	78.5	67.5
Quincy	20	10.0	57.2	77.2	67.2
Rock Island	16	8.0	59.5	75.5	67.5
Dubuque	22	11.0	55.5	77.5	66.5

The following table gives the range from low to high water as determined by us on the Upper Mississippi, to which we have added the like ranges on the Lower Mississippi, the Ohio, and Missouri, as far as we have been able to ascertain them.

Table of ranges from low to high water on the Mississippi, Ohio, and Missouri Rivers.

Place.	Range from low to high water.	Date.		Authority.	Remarks.
		High-water.	Low-water.		
	Feet.				
Saint Paul, Minn	22	1859	1864	Warren's bridge surveys	
Hastings, Minn	22	1859	1864	do	
Prescott, Wis	21	1859	1864	do	
Lake Pepin	17	......	1864	do	
Alma, Wis	18	*1859	1864	do	
Winona, Minn	17	......	1864	do	
La Crosse, Wis	16	......	1864	do	
Bad Axe, Wis	16.4	......	1864	do	
Prairie du Chien, Wis	22	......	1864	do	
Dubnque, Iowa	22	......	1864	Railroad Bridge Company	
Clinton, Iowa	18.5	1859	1864	Warren's bridge surveys	
Rock Island, Ill	16.6	......	1864	do	
Burlington, Iowa	20	1851	1864	Railroad Bridge Company	
Head of Des Moines Rapids	14	......	1853	Lieut. G. K. Warren	
Foot of Des Moines Rapids	22	......	1853	do	
Quincy, Ill	20.2	1851	1864	Railroad Bridge Company	
Hannibal, Mo	22	1851	1864	do	
Louisiana, Mo	20.5	......	1864	do	
Mouth of Illinois	39	1844	1864	R. A. Brown, civil engineer, assistant to Colonel Macomb.	Extraordinary floods.
Alton, Ill	39.5	1844	1864	R. E. McMath, assistant to General Simpson.	Do.
Saint Louis, Mo	41.4	1844	1864	City officers	Extraordinary flood; ordinary flood 35 ft.
Fountain Bluff, Ill	44	......	1864	Warren's bridge surveys	
Commerce, Mo	48	......	......	do	
Cairo, Ill	51	1858	1855	Humphreys and Abbot	

* June 8.

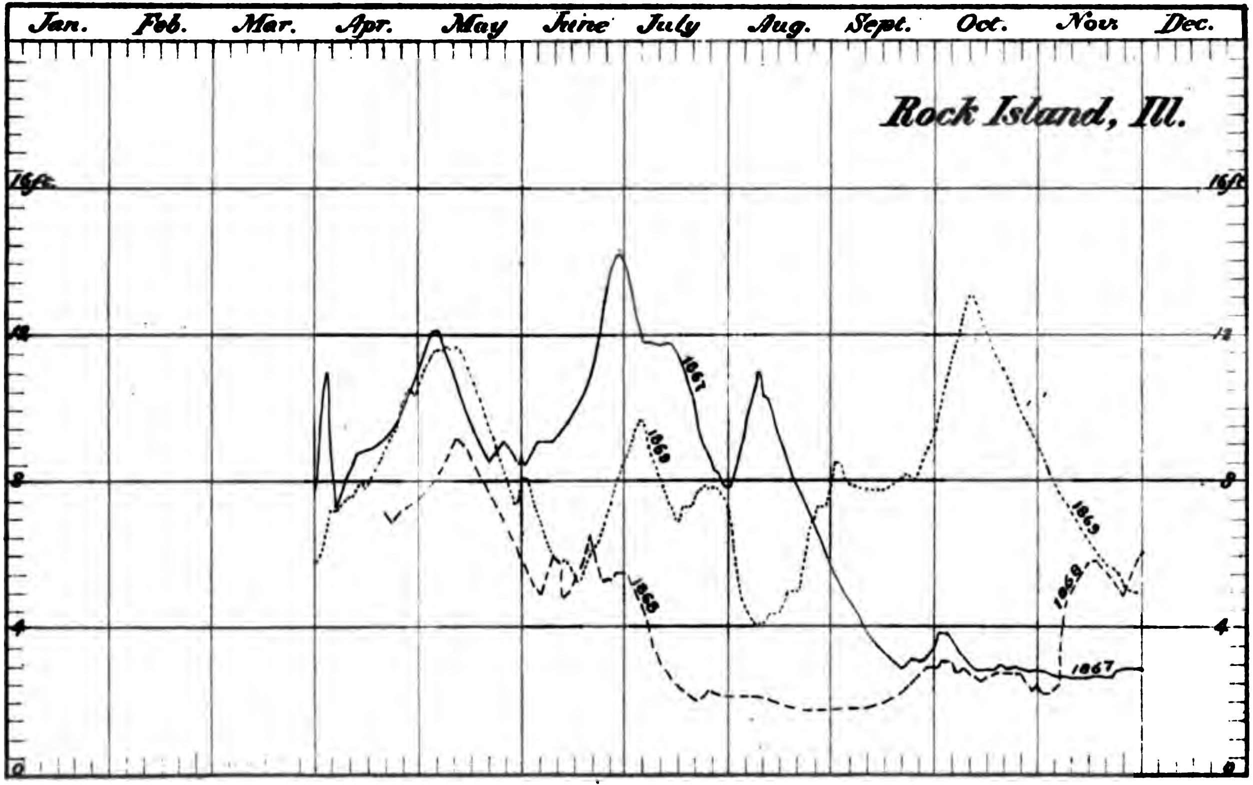
Mississippi River below Cairo.

Cairo, Ill	52.2	1862	1855	Humphreys and Abbot; changes by General Abbot (Annual Report Chief of Engineers, 1875, p. 568.)	Extraordinary floods.
Columbus, Ky	47	1858	1855	do	Do.
Memphis, Tenn	40.5	1862	1855	do	Do.
Napoleon, Ark	52.0	1862	1855	do	Do.
Vicksburg, Miss	51.2	1862	1855	do	Do.
Natchez, Miss	53.1	1862	1855	do	Do.
Red River Landing, La	44.3	1851	1851	do	Do.
Baton Rouge, La	32.4	1862	1851	do	Do.
Donaldsonville, La	24.3	1851	1851	do	Do.
Carrollton, La	15.4	1874	1851	do	Do.
Fort Saint Philip, La	4.5	1851	1851	do	Do.
Head of Passes, La	2.3	1851	1851	do	Do.

Ohio River.

Pittsburgh, Pa	35.6	1832	......	Report of Board of Engineers on Ohio bridges, in Annual Report Chief of Engineers for 1871, p. 398.	
Stuebenville, Ohio	45	1832	......	do	
Wheeling, W. Va	43.5	1832	......	do	
Bellaire, Ohio	50	1832	......	do	
Parkersburg, W. Va	50	1832	......	do	
Letart's Falls	58	1832	......	do	
Gallipolis, Ohio	54	1832	......	do	
Cincinnati, Ohio	62.5	1832	......	do	
Louisville, Ky	44.5	1832	......	do	
New Albany, Ind	63.6	1832	......	do	
Evansville, Ind	46	1832	......	do	
Paducah, Ky	52.25	1832	......	do	

Warren's Report Bridging Mississippi River. Diagram R.



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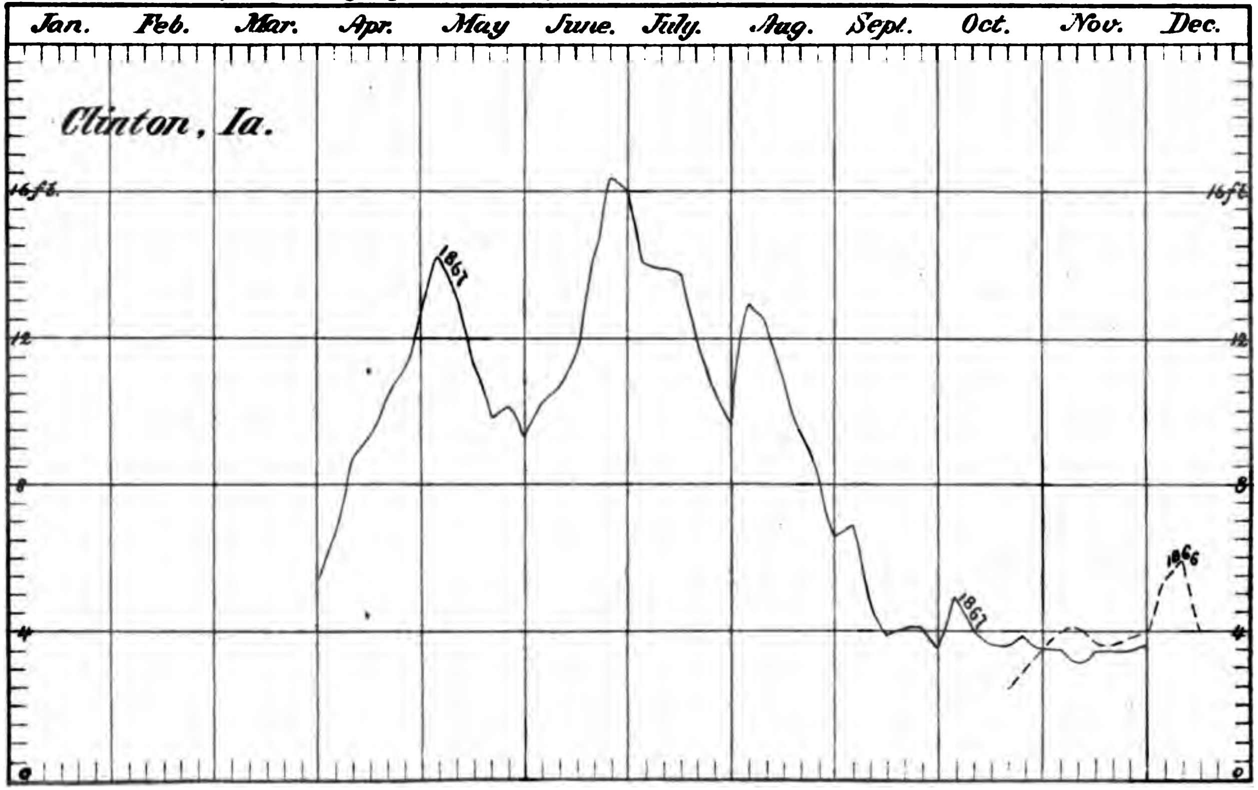
Warren's Report Bridging Mississippi River. *Diagram S.*



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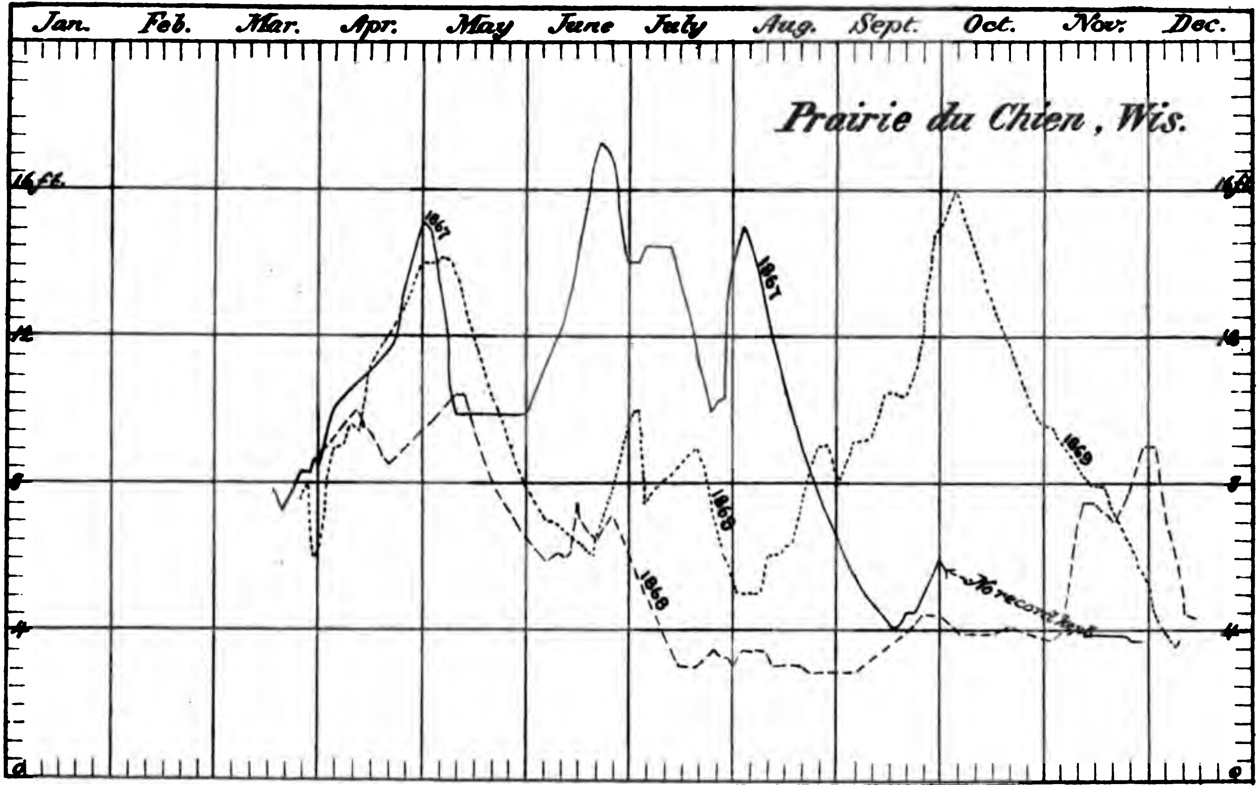
Warren's Report Bridging Mississippi River. Diagram T.



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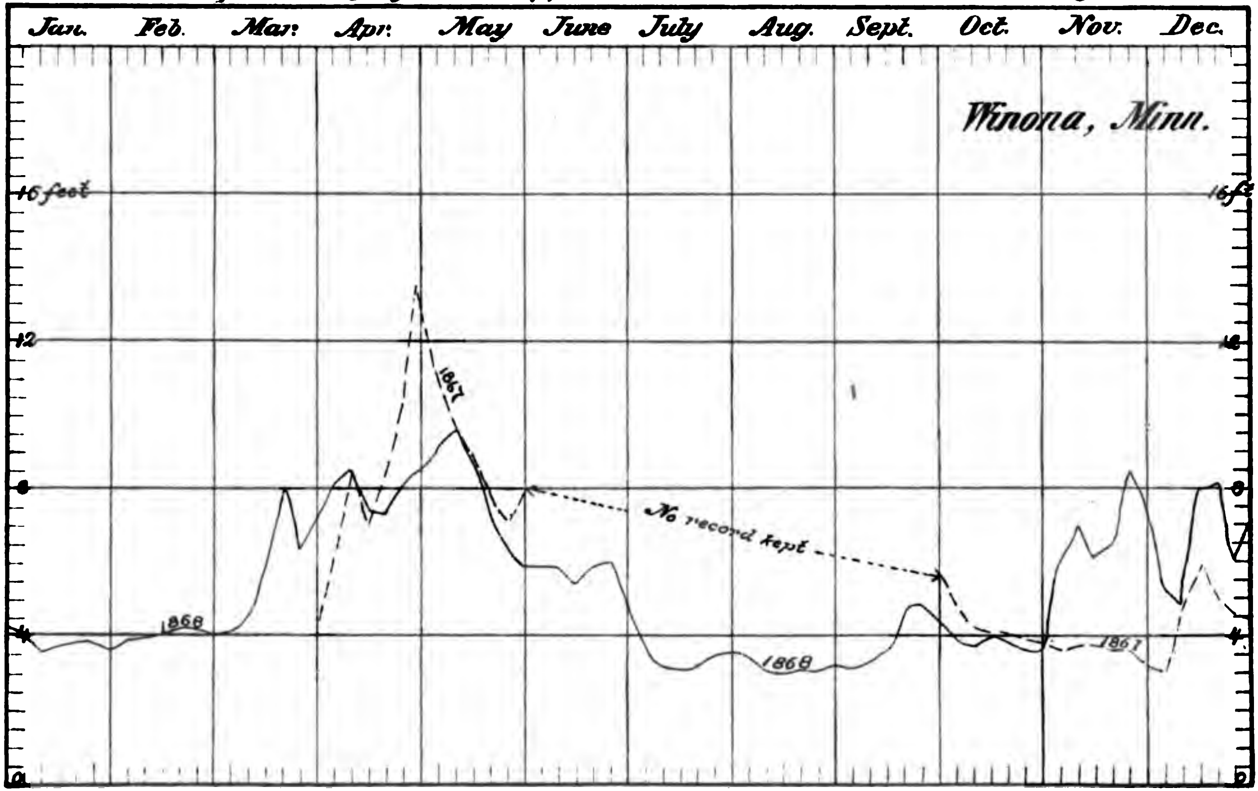
Warren's Report Bridging Mississippi River. *Diagram U.*



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Warren's Report Bridging Mississippi River.

Diagram V.

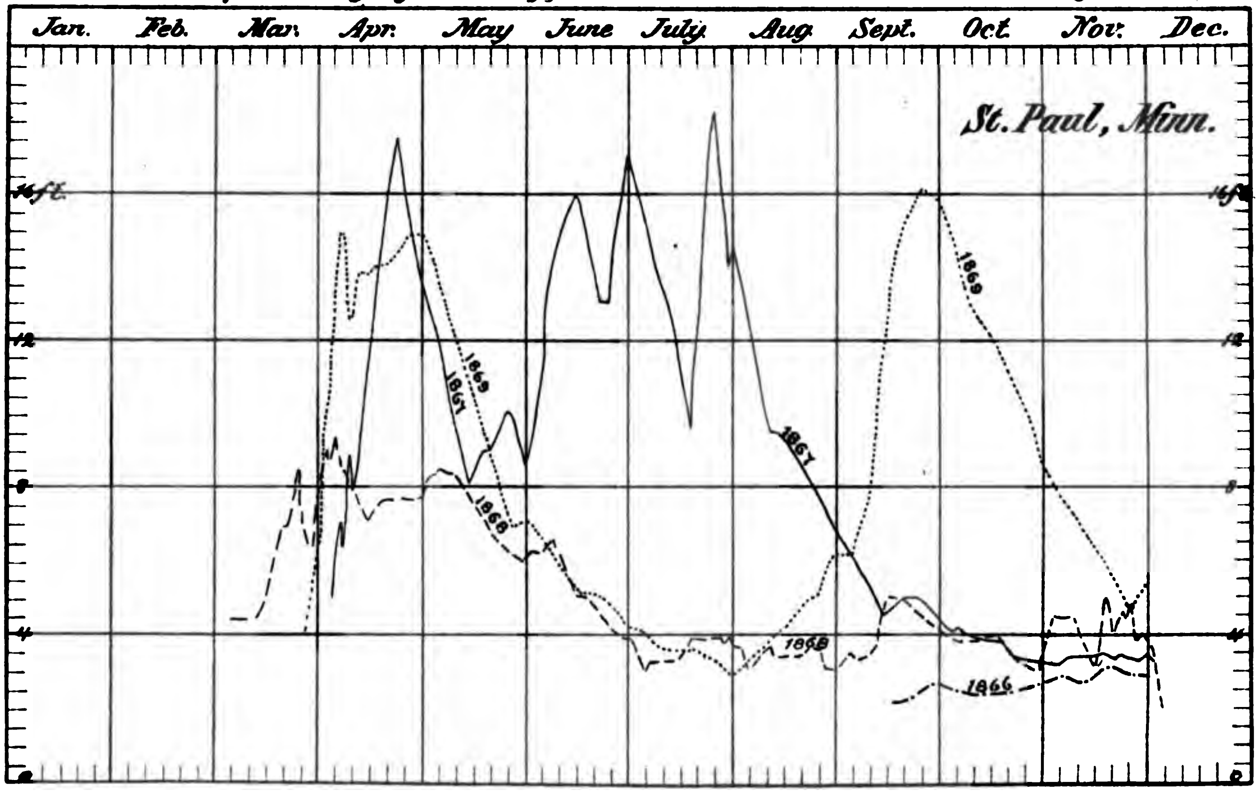

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Table of ranges from low to high water, &c.—Continued.

Missouri River.[*]

Place.	Range from low to high-water.	Date.		Authority.	Remarks.
		High-water.	Low-water.		
	Feet.				
Omaha, Nebr	19				
Nebraska City, Nebr	22	1844			
Saint Joseph, Mo	22	1844		E. D. Mason, chief engineer	
Atchison, Kans	25	1844		Gardner, Hayden's Survey of Territories.	
Leavenworth, Kans	22	1867		Corps of Engineers, United States Army.	
Leavenworth, Kans	25	1844	1867	Gannett, Hayden's Survey of Territories.	
Kansas City, Kans	37	1844			
Booneville, Mo	23.6	1844	1872	William Sooy Smith, civil engineer.	
Saint Charles, Mo	40			C. Shaler Smith, civil engineer	

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[*] High-water of 1844 was extraordinary on the Missouri, some 15 feet above ordinary floods at Kansas City and about 6 feet above at Saint Charles.

CHAPTER IV.

DESCRIPTION OF BRIDGES ON THE MISSISSIPPI RIVER FROM SAINT PAUL, MINN., TO SAINT LOUIS, MO.

Introductory remarks—Outline of treatment of each bridge—Saint Paul railway draw-bridge—Saint Paul elevated highway bridge—Hastings railway draw-bridge—Winona railway draw-bridge—La Crosse railway draw-bridge—Prairie du Chien ponton railway draw-bridge—Dubuque railway draw-bridge—Clinton railway draw-bridge—Rock Island railway and highway draw-bridge—Burlington railway draw-bridge—Keokuk railway and highway draw-bridge—Quincy railway draw-bridge—Hannibal railway and highway bridge—Louisiana railway draw-bridge—Saint Louis elevated railway and highway bridge—Bridges on the Mississippi between Saint Paul and Saint Louis authorized but not built.

Introductory remarks.—When this report was ordered by Congress in 1866, there were but two of these bridges, as they now stand, in existence—the elevated highway bridge at Saint Paul, and the low railway draw-bridge at Clinton. The former bridge has practically never been any obstruction to navigation. The Clinton draw-bridge was without authorization by Congress, but was declared a post-route in February, 1867. It is the bridge with the narrowest draw-openings authorized by Congress, and has but one draw-opening available. The old draw-bridge at Rock Island was then standing, but Congress had never authorized it, and in 1866 initiated legislation for its removal, which finally took place in 1872.

This bridge was undoubtedly the worst artificial obstruction to navigation that has been built on the Mississippi. With the exception of a very complete report upon the old Rock Island draw-bridge by the officers of Topographical Engineers, Humphreys, Meade, and Franklin, made in 1859, there was no published official report of any of the bridges on the Mississippi, or of the best kind of bridge within practicable limits to avoid obstructing its navigation. This chapter, therefore, supplies a want in the consideration of the main question of great value. The number of draw-bridges now built, and the variety of circumstances under which they were constructed, seem to be sufficient to apply the test of experience and exact observed conditions. The observations made run over periods of low and medium high-water stages at many places, and are of a kind that requires time in order to obtain opportunity to observe them. I have concluded the report upon each bridge with remarks upon its effects on navigation, and with opinions from the report of the Board of Engineers upon sheer-booms, of which Colonel Macomb was president, I being a member, and to which the maps accompanying this chapter were submitted, recommending certain modifications for the benefit of rafts. I have also made suggestions for changes to facilitate the passage of steamboats; but, to quote the language of the Board just referred to:

> The plans and locations of most of the bridges are such as to make any complete measures for the safety of navigation impossible.—(Annual Report Chief of Engineers for 1877, p. 827.)

Outline of the treatment of each bridge.—This order is followed as closely in all cases as the differences which are presented will admit. It is necessarily departed from somewhat in giving an account of the Rock Island bridge, which was designed by me.

NAME OF BRIDGE.

When built and opened.
Authority. To whom granted.

DESCRIPTION OF RIVER AND VALLEY AT THE LOCALITY.

Widths at low and high water; terraces; bluffs; rise from low to high water; slopes; bed of sand or rock; peculiarities.

SURVEYS MADE.

When; to what extent; for what purpose.

DESCRIPTION OF BRIDGE.

Approaches and arrangement of spans; grades.
Substructure; foundations; dimensions of piers; pivot pier and guard.
Superstructure; kind of; by whom built; management of draw; management of bridge; accessory works.

INFLUENCE UPON NAVIGATION.

Upon steamboats; upon rafts; directions of current; velocity; accidents.

ALTERATIONS TO LESSEN OBSTRUCTIONS.

To rafts; to steamboats.

HIGH BRIDGE.

Approaches; height above low-water.

SAINT PAUL RAILWAY DRAW-BRIDGE.

(Opened for travel in 1869.)

The only authority for building this bridge is in the act of the legislature of the Territory of Minnesota, approved February 20, 1855, incorporating the Southern Minnesota and Root River Valley Railroad Company. Section 11 of that act contains the following:

> For the purpose of constructing and using said railroad, the said corporation is authorized to construct their said railroad and the necessary bridges across and over public highways and navigable streams: *Provided*, That it be so done as not to obstruct or impede the navigation of any navigable stream. * * *

By act of the legislature of Minnesota, approved May 22, 1857, the above-named company was authorized to build a railroad from Saint Paul and from Saint Anthony to a junction at Shakopee, thence up Minnesota River, with the same powers, &c., granted to the company in act of corporation. By act of legislature of Minnesota, approved March 4, 1864, the above-named corporation was divided into two corporations, "The Southern Minnesota Railroad Company," and "The Minnesota Valley Railroad Company." By act of legislature approved March 1, 1870, the latter name was changed to Saint Paul and Sioux City Railroad Company. This company built the bridge and operate it. The Milwaukee and Saint Paul Railway Company run their trains over it.

DESCRIPTION OF THE RIVER AND VALLEY AT THE LOCALITY.

(See Diagram 4.)

The width of the low-water river at the site of the bridge is about 1,300 feet; within 1,000 feet above this width decreases to 700 feet. The high-water width here is about 3,000 feet. The left bank is bounded by a low rock terrace about 50 feet high; on the right side of the valley the bluff rises to the height of 125 to 150 feet. This bridge is but 2 miles above the highway bridge at Saint Paul. The rise from low to high water is about 22 feet. The current is gentle at low water; at high water it is probably as much as 6 or 7 miles per hour. The slope of the water's surface is about 1 foot per mile.

The bed of the low-water river is composed of sand; its depth is not known to me.

SURVEYS.

In September, 1866, a survey was made of this section from mouth of Minnesota River, 4 miles above to 9 miles below. This survey determined the lines of the low banks, of the overflowed bottom-lands, and of the bluffs, the slope of the water's surface, and, by soundings, the depth of the river. The survey was made with a view to obtain a knowledge of the river preparatory to devising a plan for its improvement. The piers of the bridge had been commenced at that time and careful soundings were made about them. In October, 1868, a special survey was made at this bridge, including soundings and current observations. In September, 1876, an examination was made, but no current observations were taken, they having been made by Colonel Farquhar, in July preceding.

DESCRIPTION OF BRIDGE.

(See Diagram 5.)

Approaches.—Commencing at the bluff on the right side of the valley, the bridge approach crosses a lagoon or lake called Pickerel Lake, on a curve of about 1,340 feet radius and about 1,100 feet long, then on a straight line to the abutment on the left bank. The left bank approach is on a curve of about 1,145 feet radius. The approach on the right bank is of trestling resting upon piles sawed off near the surface of the ground and in the lake just above low-water. The approach on the left bank is on an embankment.

Arrangement of spans.—The first span, commencing on the right bank, is 150 feet from centers; the next two (pivot-draw), 270 feet from end to end, with clear openings of 114 feet; then six spans, 150 feet each; in all, 1,320 feet from end to end of bridge.

Substructure.—The piers of this bridge are, with the exception of the pivot, 22 feet long and 7 feet wide on top, with a batter of ½ inch to the foot. All have triangular ends, except the one standing on the left bank. The pier to the right of the pivot, the pivot, and two piers to the left, rest upon piles cut off below low-water. The others rest upon the bed of the river, and are protected by riprap. The pivot-pier is circular in plan, 30 feet in diameter. All of the piers are of masonry. The stone for them came from the bluffs in the immediate neighborhood, and is magnesian limestone. All of the small piers standing in the river, except the one on the right of the pivot, have detached ice-breakers. These ice-breakers are timber cribs, filled with riprap, resting upon the river bottom; they are rectangular, with a triangular nose or starling, with a slope of 2 on 3; dimensions on top 12 feet wide, 19 feet long, with the nose 9 feet, making whole length 28 feet on top. All of these ice-breakers, except the one to the pier on the left of the pivot, are placed on a line, making an angle to the left of 15 degrees with the axis of the piers. The pivot-guards or draw-rests are timber cribs, planked and weighted with riprap.

Superstructure.—The bridge is a wooden Howe truss; the short spans are 22½ feet high and 19 feet wide out to out. The draw-span is 9 feet high at the ends and 26 feet at the center. The bridge-truss was built by the Saint Paul and Sioux City Railroad Company. The draw is opened and closed by men with levers.

At the time of our examination, in September, 1876, the company were putting bents of trestle under each span, the bridge having become unsafe by the decay of the chords. This early decay (the bridge had been built but 6½ years) of the timber in the chords is said to be due to want of care in its selection and to the use of oak wedges in the pine chords. The acid of the sap from the oak wedges is said to have caused decay in the pine. An examination of the chords where most decayed showed it had taken place to a greater extent about these wedges than in other parts, but whether more than is properly chargeable to the excess of moisture here, I cannot say.

The whole bridge superstructure, except the draw-span, was to be rebuilt in the winter of 1876–'77.

INFLUENCE UPON NAVIGATION.

In 1866, 1867, and 1868, the channel of the river was along the left bank, at the foot of the rocky bluff from Williams's Ferry, 5,000 feet above the bridge, to a point 1,400 feet above the bridge; from this latter point the channel crossed to the right bank, reaching it a short distance below the bridge. This crossing was gradual through this distance, so that the piers of the bridge were nearly parallel with the current. This was the case when our current observations were made in 1868. At that time the piers were partially built, all of the foundations being in, and the masonry built to the level of the water. The pivot-guards and ice-breakers were not then built. Current observations made in July, 1876, by Colonel Farquhar, United States Engineers, with the water at 3.1 feet above low-water, show a marked change in the direction of the current. The "*crossing*" from left to right bank, instead of commencing at a point 1,400 feet above the bridge, commenced only 600 or 700 feet above, the current crossing the bridge axis obliquely, making an angle of 10 degrees with the axes of the pivot-guard and rest-piers. This change in the direction of the current was due to the formation of a bar running out from the right bank above the bridge; the lower end of this bar, at the time of these observations, was within 500 feet of the bridge. This change has made the right draw-opening unsafe, and it is never used by steamers descending the river.

ALTERATIONS TO LESSEN OBSTRUCTION TO NAVIGATION.

It is probable that the extension or recurrence of the sand-bar cannot be prevented without rectification of the river for some distance above the bridge. This the bridge company should be compelled to do for the sake of the navigation on the Minnesota River.

HIGH BRIDGE.

High ground could have been found for the approach on the left bank where the width of the valley would have been but 3,300 feet. This length of approach is small in a high bridge over so large a stream as the Mississippi at this point. A continuous bridge here should not be less than 77 feet above low-water.

SAINT PAUL HIGHWAY BRIDGE.

(This bridge was commenced in 1857, and completed and opened for travel in 1858.)

Authority.—The building of this bridge was authorized by the Territorial legislature of Minnesota, by act approved March 4, 1854. This act is entitled "An act to incorporate the Saint Paul Bridge Company." Section 12 of this act, which contains the provision fixing length and height of spans, and provisions in reference to navigation, is as follows:

> Said bridge shall be of such material as the stockholders may deem expedient, and shall be so constructed as to cover the main navigable channel of the river by a span at least three hundred feet from pier to pier, the lowest part of which said span shall be at least sixty feet above high-water mark, and said company may construct other abutments, piers, and guards to said bridge, at such distances from each other and at such places as may be deemed necessary, either on the street from which such bridge shall lead, on the island opposite said street in the said river, or on the mainland on the opposite side of said river: *Provided*, That nothing in this section shall be so construed as to warrant the obstruction of any public street or the navigable channel of said river.

The span over the main channel was built 240 feet long instead of 300 feet, as provided by the act. I have not been able to find that any additional legislation changed the provisions of the act here referred to.

DESCRIPTION OF THE RIVER AND VALLEY AT THE LOCALITY.

(See Diagram 4.)

The Mississippi River, at the site of the bridge, is divided into two channels by an island. The distance between the low-water banks on the line of the bridge is about 1,200 feet. The usual low-water width of the river is about 800 feet. The high-water width from buff to bluff varies from 3,000 to 6,000 feet. The bluffs are of sandstone, capped with limestone, and are about 125 feet high. The bottom-land is overflowed at high water from 8 to 10 feet or more. The current is, at time of low-water, gentle at the bridge; at high water it is about 6 miles per hour. The rise from low to high water is about 22 feet. The slope is 0.9 foot per mile.

SURVEYS.

In September, 1866, a survey was made of the river from the mouth of the Minnesota, 6 miles above, to Red Rock, 7 miles below. This survey consisted in a determination of the low and high water banks, the slope of the water's surface, soundings, and observations for volume of discharge. The object of the survey was to gain a knowledge of the river to enable me to plan works for the alleviation of the difficulties attending navigation at low-water.

In 1867 observations were made through nearly the whole season near this bridge, for volume of discharge. The survey of the river was continued from Red Rock to Hastings.

In 1868 special surveys were made at this bridge, including soundings and current observations.

The bed of the river at this bridge is composed of sand. The rock appears on the left bank, rising to the height of 90 feet above low-water, almost perpendicularly.

DESCRIPTION OF BRIDGE.

(See Diagram 6.)

Commencing at the bluff on the right bank, we have an embankment about 1,600 feet long, built about 4 feet above high-water; through this embankment were three openings of about 45 feet each. From the end of the embankment to the first pier was 375 feet of trestling in bents 30 feet apart; then 7 spans 140 feet long from centers; then the channel-span, 240 feet, and a span of 80 feet over the railroad and highway along the bank of the river.

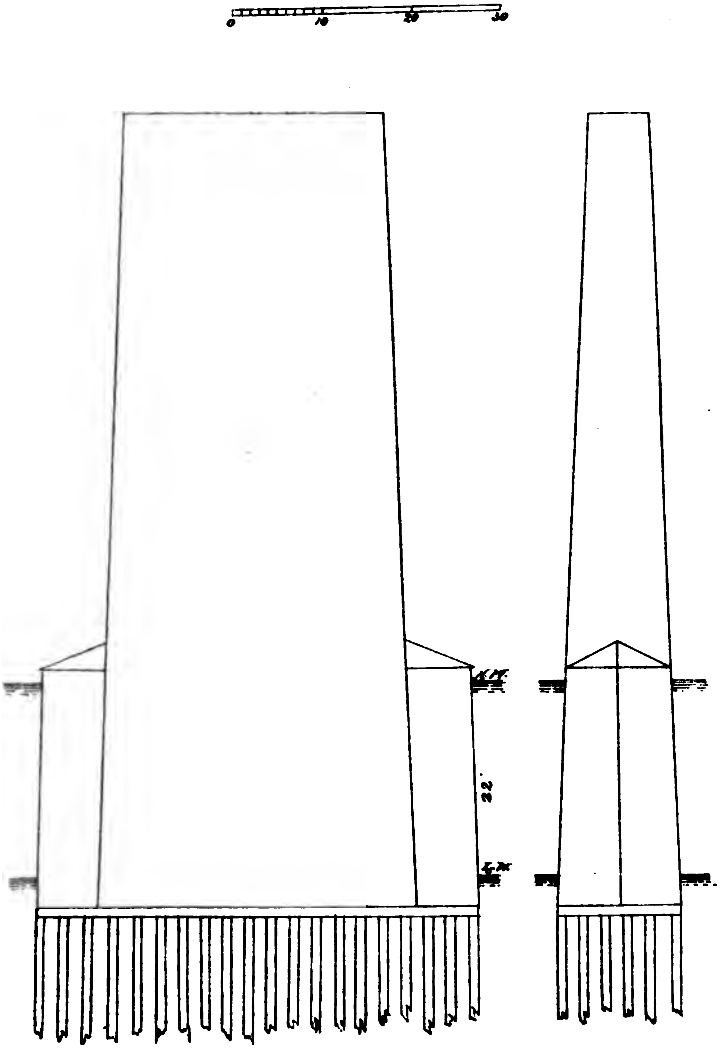
Grades.—The roadway on the trestle and short spans to the right of the channel-span is on a grade of 1 on 20. The part on the channel and short span to the left is on a grade of 1 on 28.

Substructure.—The trestling is of the usual kind, pine timber formed in bents. The first pier on the right bank rests upon a grillage of timber placed below low water. This pier is rectangular, 20 feet long and 5 feet wide on top, with a batter of half-inch to the foot. The others are 7 feet wide with the same batter. Those standing in the river have triangular ends up to highest water; these rests upon piles cut off below low water. The two piers standing on the island are rectangular without starlings, and have no piles under them. The masonry rests upon the grillage which rests upon a bed prepared by throwing in riprap. The safety of these piers and the three spans resting on them depends upon the preservation of the island. Since the erection of the bridge, from 150 to 200 feet of the island have been washed away. This washing is probably due to the filling out on the left bank in Saint Paul. The importance of preserving this island has been frequently brought to the attention of the city authorities, but up to October, 1876, but little had been done toward it. The channel-piers (see Diagram W) are 30 feet long and 7 feet wide on top, 86 feet above low-water, with a batter of half-inch to the foot. The shore-end of the 80-foot span rests upon the rock of the bluff upon which this part of the city of Saint Paul is

St. Paul, Minn.

ELEVATIONS OF PIER 2.

Scale of Feet



AM. PHOTO-LITHO. CO. N.Y. (OSBORNE'S PROCESS)

built. The piers of the bridge are of masonry, from stone quarried in the bluff on the right bank about three-quarters of a mile above the bridge. This stone is magnesian limestone; it lies here immediately above the soft sandstone, generally in thin layers. It is used in many of the buildings of Saint Paul, and stands exposure very well when laid with its quarry-bed down. If laid differently it disintegrates rapidly by the infiltration of water between the strata and the action of the frost. The upstream starling of the right pier of main span has had pieces knocked off of it by floating logs and ice. This part of these piers should have been of more durable stone.

Superstructure.—The original structure was built of wood by Mr. J. S. Sewell, civil engineer, in 1857 and 1858, of a peculiar pattern, designed by him. All of the spans except the channel-span were deck-trusses, with roadway on the top chord. The channel-span is a through span; its lowest part is 63 feet above high water. A peculiar feature of this bridge is the grade of the roadway. The roadway, at the end toward the right bank of each span, is on the upper chord, and at the other end 7 feet above; the next span is placed 7 feet above the other, and so on to the channel-span.

The main span was rebuilt of wood in 1869 and 1870, and the others in 1872. In 1875–'76 the channel-span was replaced by an iron one. The bridge was built by a company and toll charged for its use; it has since passed into the control of the city of Saint Paul and is now a free bridge.

INFLUENCE UPON NAVIGATION.

This bridge when built was practically no obstruction to either raft or steamboat navigation. At that time the only means of reaching Saint Paul and the country above was by the river, and steamboat navigation was very flourishing. This accounts for the satisfactory provision made for it.

The first railroad communication to Saint Paul was late in 1867, nine years after the opening of the bridge.

The filling out on the Saint Paul side below the bridge occupies a part of the approach to the channel-span and deflects the current toward the island, making the shore part of this span in a slower current than the part toward the right pier. This filling out has not, as yet, greatly impaired the safe passage of this bridge by steamers, but if allowed to go on it will seriously injure it. Had the same amount of filling been above instead of below the bridge it would have obstructed the passage of this bridge very much.

There is much need for doing something on the Mississippi to prevent such injury to navigation and secure it against the injury which parties, other than the bridge companies, cause to it in the vicinity of the bridges.

HASTINGS RAILWAY DRAW-BRIDGE.

(Opened for railway travel in 1871.)

Authority.—The only authority for the building of this bridge known to me is an act of the legislature of Minnesota, approved February 7, 1867, entitled—

> AN ACT to incorporate the Hastings, Minnesota River and Red River of the North Railroad Company.
>
> SECTION 22. * * * This corporation are hereby authorized and empowered to extend their road by a bridge across the Mississippi River, and to farther extend and construct and use their road with all its appurtenances to the mouth of the Saint Croix, and build and construct a bridge across said river to the town of Prescott, in Wisconsin, if they shall deem it expedient to do so, provided that said bridges across the Mississippi and Saint Croix Rivers shall be so constructed as not to obstruct the navigation of said rivers.

The name of this company was afterward changed to the Hastings and Dakota Railroad Company.

All the bridge companies that have built bridges on the Mississippi, below the junction of the Saint Croix, where its channel forms the boundary line between the States, and over the Saint Croix River (where it forms part of the boundary between Wisconsin and Minnesota), have thought it necessary to have them declared post-routes by act of Congress.

On the part of the Mississippi which lies wholly within the State of Minnesota such action of Congress has not been sought, nor have the bridges been built according to the provisions of any act of Congress. There seems to be no reason, however, why any such exception should be made.

DESCRIPTION OF THE RIVER AND THE VALLEY IN THE LOCALITY.

(See Diagram 7.)

The river, which at low water for two miles above runs along at the foot of the rocky bluff of the left bank, crosses just above the town and strikes the low rock bluffs of the right bank, making there a sharp bend. The river is thus thrown into one narrow channel, which at low water is but 400 feet wide with a depth from 18 to 22 feet. A similar case is presented in the bend above the town of Hannibal, Mo. The rise from low to high water is 22 feet. The current is gentle. The high-water river, which extends from bluff to bluff, is about 4,000 feet wide; this is less than the general width of the valley in the vicinity and narrower than at any place below, except at Commerce, Mo. The low rock of the right bank gives an easy and secure approach; the narrow low water river requires only a minimum of bridging; and the river bend allows the railroad to cross the valley with but little deviation from the general alignment; so that this is an unusually economical site for bridging the river.

SURVEYS.

In September, 1866, a survey was made from Hastings, Minn., to Prescott, Wis., covering about 4 miles of river, the water at the time being about 2½ feet above low-water. Both shores were surveyed, levels run, soundings made, and volume of discharge measured. In October, 1867, a survey of the river from Saint Paul to Hastings was made. This survey covered a small portion of the river surveyed in 1866. In September, 1876, a survey of the river at the site of the bridge, and current observations, were made, with the water 3.85 feet above low-water.

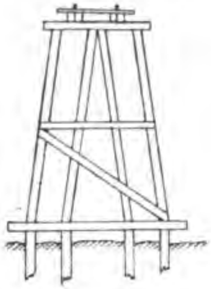
DESCRIPTION OF THE BRIDGE.

(See Diagram 8.)

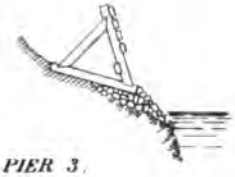
Commencing on the right bank the approach is an embankment of 300 feet; then 235 feet of trestle to the right rest-pier; then a draw-span of 300 feet over all, two spans of about 150 feet each, and one of 106 feet; then 2,286½ feet of trestling to a bridge of two spans, each 105 feet; then trestle for 700 feet to the embankment. The bridge is on a straight line from right bank to 160 feet beyond pier 6, numbering from right bank toward the left; then a 2° curve for about 1,950 feet; a tangent to this curve is nearly parallel with the bank of the river above. From the end of this curve it is on a straight line across the short bridge to the bank of the river above.

Hastings, Minn.

TRESTLE BENT

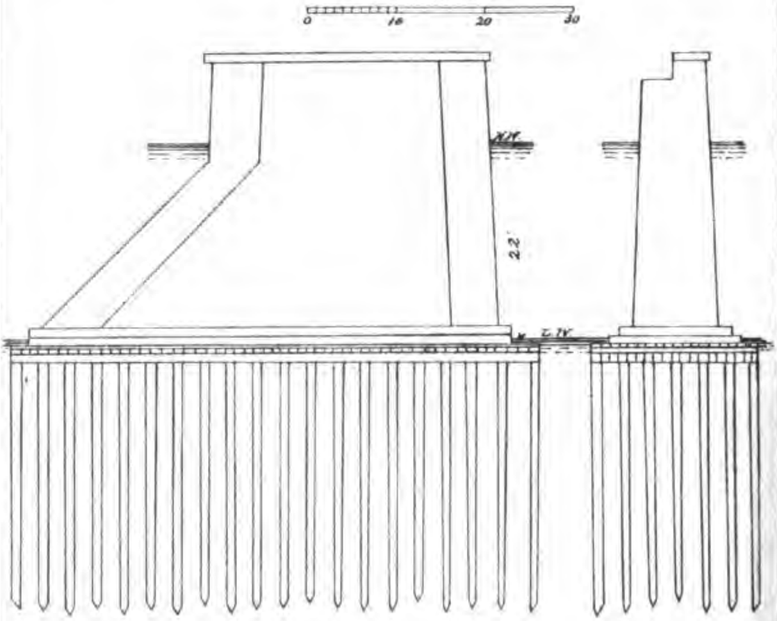


SHEER



ELEVATIONS OF PIER 3.

Scale of Feet



AM. PHOTO-LITHO. CO. N.Y. (OSBORNE'S PROCESS)

Grades.—The grade of the road is level from the right bank to the end of the bridge, and then descends at the rate of about 15 feet per mile for 1,800 feet; then level across the short bridge to the embankment.

Substructure (see Diagram X).—The piers are built of the magnesian limestone found in the vicinity; the most of it from Barn Bluff, at Red Wing. They all rest upon piles sawed off, I was told, below low water. The draw-rest piers are 7 feet wide under coping; the others in the river 6 feet wide; those of the short spans near the bluff 5 feet wide. The draw-pier is 26¾ feet in diameter on top, with a batter ½ inch to the foot. The rest-piers are each 7½ feet wide on top, 21 feet long, with triangular ends 5½ feet long each; making total length 32 feet. The batter of these piers is ½ inch to the foot. The pier at right end of draw rests upon the rock of the natural bank, some 6 feet above low water and about 15 feet from the shore-line at low water, reducing the water-way to this extent. The rest-pier at left end of draw (No. 3) has the same dimensions on top, but has a starling commencing 18½ feet above low water, with a slope of 1 on 1.

The next pier left (No. 4) is 6 feet wide on top (under coping) and 30¾ feet long, including the triangular ends, the rectangular portion being 21 feet. This pier has a starling of same dimensions as No. 3. The next two piers to the left are of same dimensions without starling. The three piers of the short bridge in the north approach are 25½ feet long and 5½ feet wide on top. Their ends are semicircles in plan with a radius equal to half the width of the pier, the rectangular portion being about 20 feet long. The draw-rests are cribs resting upon the bottom of the river. They are about 20 feet above low water. The lower one is tilted, probably by reason of scour at the time of sinking it. This tilting amounts to a difference of 1½ feet in the elevation on the opposite sides of the lower end.

Superstructure.—The draw-span and two adjoining 150-feet spans have iron trusses of the Post pattern. They were built by the American Bridge Company of Chicago. The three 105-feet spans are of a combination of wood and iron and of the same form of truss. The draw is worked by men with levers. The lowest part of the structure is 8½ feet above the high water of 1870, and extreme high-water is at least two feet higher.

INFLUENCES UPON NAVIGATION.

The left draw-opening is 130 feet in the clear, and the right draw-opening 115 feet; the clear width of this span is decreased by the rest-pier being placed on the bank some 15 feet from the shore. The two spans next to the draw are about 140 feet each in the clear. The location of the bridge immediately below a very sharp bend in the river prevent it being seen by descending boats until within about 1,600 feet—too near for heavily-loaded boats to approach, especially in time of high water and swift current, and wait for the opening of the bridge.

ALTERATIONS TO LESSEN OBSTRUCTIONS TO NAVIGATION.

A sheer or fender has been built along the right bank up as far as the head of the draw-rest. The passage of the bridge would be improved if this sheer were extended up river so that boats could land against it and drop through. Another reason for extending this sheer is that the shore is so rocky that to drop down against it is to endanger boats or rafts.

A signal placed above the bend so it could be seen from a boat coming down, before she got too near the bridge, would give time and space to land above the bridge if it could not be opened for its passage. This signal could be operated from the bridge, and would not be expensive.

HIGH BRIDGE.

A high bridge at this place would have high ground on the right bank at a short distance from the river. The approach on the left bank could be made for the most part on the present line and require but little increase in the length of the trestling. One span of 300 feet would be all that need to be high. This should be 55 feet above high water, which would be about 77 feet above low water.

WINONA RAILWAY BRIDGE.

(Opened for travel in 1871.)

This bridge was built by the Winona and Saint Peter's Railway Company in 1869-'70, under the authority of the act of Congress approved July 25, 1866.

GENERAL DESCRIPTION OF THE RIVER AND VALLEY.

(See Diagram 9.)

Winona is situated on a sand and gravel terrace on the right bank of the Mississippi whose level is but a few feet above the extreme flood-heights, and at high stages the water passes behind the town, and between it and the bluff. The channel has been permanent along this terrace where the bridge is situated. The ordinary water-way is divided by a low wooded island, near the lower part of which the bridge crosses, but the island is overflowed to a depth of several feet at high water. The ordinary width of the main water-way at the bridge is 1,000 feet, that of the lesser one 700 feet. There were two other smaller sloughs or water-ways running through the low banks on the left bank, forming water-courses at medium stages, while at highest stages the whole bottom overflows to a depth of several feet.

The width of the river between the bluffs (which are near 400 feet high and composed of sandstone and limestone, some of which answers for building) is about 3 miles. The rise from low to high water at this place is about 17 feet.

The slope of the surface at common low water averages about $\frac{7}{10}$ foot per mile; and the current is about 3 miles per hour at a stage 5.4 feet above low water. We have no measure of it at high water.

SURVEYS.

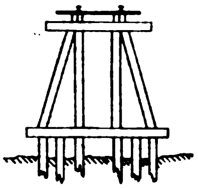
This locality was surveyed by us in September, 1866; again in October, 1867 (this latter time forming the terminus of a continuous survey from Lake Pepin); again in 1868, at which time the railroad company had obstructed the water-course on the Wisconsin side of the island with piles; and finally in September, 1876. All these are shown on our maps.

None of the surveys but the last was made after the bridge was built.

Warren's Report Bridging Mississippi River. *Diagram Y.*

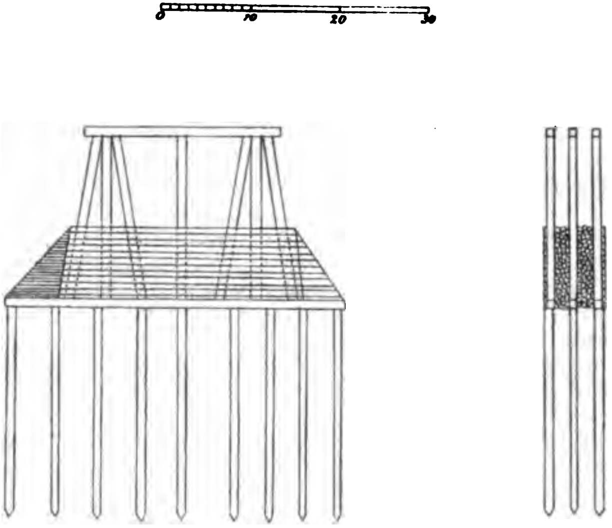
Winona, Minn.

TRESTLE BENT



ELEVATIONS OF ISLAND PIER 10.

Scale of Feet



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DESCRIPTION OF BRIDGE.

(See Diagram 10.)

Arrangements of spans and approaches.—Commencing on the west bank, the bridge is reached by trestling for about 2,100 feet, on a maximum grade of 1 in 100, crossing two streets now in use on trusses 40 feet long.

The first span is 80 feet from centers. It is a Howe truss. The next going east is the draw span which is 360 feet over all, giving clear openings of 160 feet. This span is of iron and is of the Post patent.

The next two spans are each 250 feet from centers, and are Howe trusses. This brings us across the main river to the low island. For the next 1,000 feet, trestling was used up to the time of our survey; it was then being replaced by 7 spans of wood, each 142½ feet in length. This was made necessary by reason of the scour about the piles on which the trestle rested. Driftwood lodged against them at time of high water, and scour took place to such extent as to endanger the structure.

The slough is crossed by Howe trusses, 4 spans of 160 feet each from centers. Then come 9 queen-post trusses, of about 45 feet length each, resting upon piles. There is then 487 feet of embankment over bottom-land to a slough 360 feet in width, crossed by pile trestling. This is to be replaced the coming winter (1876–'7) by two trusses of 142½ feet span, and one of 45 feet. Then comes an embankment 2,805 feet, then 75 feet of trestling, then two spans of 132½ feet, and then 345 feet of trestling across the slough to embankment, making 3,988 feet of bridging exclusive of the trestle approach on the west bank. The draw of this bridge is turned by a small steam-engine placed on the turn-table. Provision is also made to turn it by hand.

Substructure.—The piers, commencing on the west bank, are of the following dimensions: The first, at west end of the 80 feet span, Howe truss, is of masonry, resting upon piles. It is inside of the low-water line, and is protected by riprap.

The second pier, upon which the west end of the draw rests, is 30 feet long and 8 feet wide, under the coping. The starling on the upper end of the pier commences 8.8 feet below the top.

The lower end of the pier is square. The batter, on sides, ends, and starling, is about $\frac{1}{24}$. The pivot-pier (No. 3) is 33 feet in diameter on top, with a batter of $\frac{1}{24}$. The guard rests are cribs resting upon piles, sawed off at about 4 feet above low-water surface; they are 32 feet wide 34 feet from the pier. From the guard-rests a row of piles, capped, runs to the middle of each side of the pivot-pier, where they are 3 feet outside of the masonry.

The next pier east (No. 4) is of the same dimensions as No. 2, except the starling, which has a greater slope, probably 4 inches to the foot.

The next pier, No. 5, is 7 feet wide under the coping, but in other respects the same as No. 2. These piers all have cribs around them filled with stones, which come up to within about 2 feet of the water's surface at time of survey, and they have detached ice-breakers. The next pier is of timber 37 feet long by 11 feet wide, resting upon what appeared to be a crib, filled with riprap, with other riprap thrown in around it on the river side 15 feet wide at a level, 6 feet above low-water. The next 6 piers across the island are each three trestle bents resting upon piles cut off one foot above present water. (See Diagram Y.) These bents are planked up on the outside to 10 feet above low-water and filled with riprap. The entire length on the bottom is 39 feet including the triangular ends; these are, 6 feet at the upstream end and 4.8

feet at the downstream. The upriver triangular nose is of 3-inch oak plank, laid flatwise. The width of the pier on the top is 6 feet and its length about 24.

The next pier, No. 12, is on the west bank of the slough. It is composed of 40 piles in 4 rows. Around these piles a crib was built and filled with riprap. A large mass of riprap was also placed about the crib. The piers on top are 21 feet long and 10 feet wide. The crib is about 45 feet long and 15 feet wide. These piers make an angle of about 75° with the axis of the bridge, inclining to the right-hand side, looking upstream.

Detached ice-breakers are built above each of the piers in the slough, 33 feet long and 14 feet wide. They are of two rows of piles driven close together, capped and waled. The nose is triangular, forming 9 feet of the length and planked. The cut-water is covered with railroad iron. The whole is filled with riprap up to the top, 13 feet above low water. The lower end of ice-breaker is 82 feet from upper side of bridge, in prolongation of the center line of pier. Around the ice-breaker the riprap extends out about 10 feet on all sides above water, at time of survey.

At each of the shore piers (Nos. 12 and 16) a sheer has been built. The west sheer is 300 feet long and the east 176 feet long. They are of two rows of piles, capped, about 16 feet above water at time of survey, with riprap thrown against and between them, and they flare so as to turn drift into the open spans.

Beyond the sixteenth pier come the nine queen-post trusses, resting upon bents of piling, recently built in place of pile trestling that had become too much decayed to be trustworthy.

The piers of the slough bridge consist of three rows of piles with riprap around and between them. These piers have the general direction of the slough, and make an angle of 73° with the axis of the bridge.

INFLUENCE UPON NAVIGATION.

Steamboats.—The piers of this bridge were parallel with the current at the stage when it was examined by us. The arrangement of the draw-spans is practically next the shore (the right bank), following the example of the Rock Island bridge.

The arrangement of the pivot pier and its guards is not good. The projections at the pivot are bad to strike against, especially if going at any ordinary speed.

Rafts.—Large rafts are compelled to divide in two parts to pass. There is some difficulty occasioned by reason of a sand-bar about 2,000 feet above, which sometimes closes down to near the right bank, and here Yeoman's boom occupies a desirable part of the navigable channel, from which it should be removed. The sides of the pivot pier and guards are not as smooth as they should be to prevent injury to rafts in rubbing along them. The landings made along the shore leave it too jagged for safe passage of rafts. It seems probable, too, that the span left for rafts at high water in the water-way east of the island is too narrow.

ALTERATIONS TO LESSEN OBSTRUCTIONS TO NAVIGATION.

Sheer-booms.—The Board of Engineers on sheer-booms recommended that Yeoman's log-boom be drawn in towards the right bank at least 100 feet, and that a sheer-boom be placed above the bridge with its lower end at the right rest pier, extending upstream 150 feet above the elevator.

Pivot-pier guards.—These guards should be rebuilt so as to have the same width the whole length from the draw-rest above to the one below the pivot. Floats should not be used as guards, which should be f amed and planked up to 4 feet above high water.

HIGH BRIDGE.

A high bridge at this site would require long approaches on both sides, because the banks are low. The least height should be 75 feet above low water, or 58 above high water.

If a high bridge is built, the best location is at Trempealeau, about 12 miles lower down on the river, where high banks, about 3,500 feet apart are found on both sides. A single bridge here might have been made to accommodate the railroads approaching both Winona and La Crosse.

LA CROSSE RAILWAY BRIDGE.

(Opened for travel in December, 1876.)

Authority.—By act approved February 21, 1868, the Southern Minnesota Railway Company were authorized to construct and operate a railroad bridge across the Mississippi River, between the city of La Crosse, Wis., and a point opposite in the State of Minnesota, under the same general provisions as were contained in the act approved July 25, 1866, authorizing the bridge at Quincy. No bridge has been built under the act of February 21, 1868.

By act approved April 1, 1872, the Milwaukee and Saint Paul Railway Company were authorized to build a bridge at any point they may select between the county of La Crosse, Wisconsin, and the county of Houston, Minnesota.

The only essential differences between this act and that approved July 25, 1866, are embraced in sections 4 and 5, which are as follows:

> SEC. 4. That all railway companies desiring to use said bridge shall have and be entitled to equal rights and privileges in the passage of the same, and in the use of the machinery and fixtures thereof, and of all approaches thereto, under and upon such terms and conditions as shall be prescribed by the Secretary of War, upon hearing the allegations and proofs of the parties in case they shall not agree.
>
> SEC. 5. That the structure herein authorized shall be built and located under and subject to such regulations for the security of navigation of said river as the Secretary of War shall prescribe; and the said structure shall be at all times so kept and managed as to offer reasonable and proper means for the passage of vessels through or under said structure; and the said structure shall be changed at the cost and expense of the owners thereof from time to time, as Congress may direct, so as to preserve the free and convenient navigation of said river. And the authority to erect and continue said bridge shall be subject to revocation, modification by law, whenever the public good shall, in the judgment of Congress, so require, without any expense or charge to the United States.

The act approved June 4, 1872, still further increased the discretionary power of the Secretary of War; this was as follows:

> AN ACT regulating the construction of bridges across the Mississippi River, approved June 4, 1872.
>
> *Be it enacted, &c.*, That all bridges hereafter constructed over and across the Mississippi under authority of any act of Congress shall be subject to all the terms, restrictions, and requirements contained in the fifth section of the act to authorize the construction of a bridge across the Mississippi at or near the town of Clinton, Iowa, approved April 1, 1872; and in locating any such bridge the Secretary of War shall have due regard to the security and convenience of navigation, to convenience of access, and the wants of all railways and highways crossing said river.

A design for bridging the Mississippi River about two miles above La Crosse, near the lower end of Minnesota Island, was submitted to the Secretary of War on May 23, 1872, by the president of the Milwaukee and Saint Paul Railway Company. This location was opposed by the city of La Crosse, and remonstrance was made to the Secretary of War against the adoption of it. This opposition desired the bridge located below the mouth of Black River, and centrally as regards all the railway and highway interests, so that there might be but one bridge. The whole matter was referred to me by letter from the office of the Chief of Engineers, dated June 8, 1872. I submitted a report dated June 29, 1872. The general view taken was that the opposing interests should settle their differences among themselves. The subject was then referred to a Board of Engineers, of which Col. J. N. Macomb was president. They submitted one report dated July 29, 1872, and a second report dated September 26, 1872. The Board favored the location at the town.

The papers relating to the whole subject were printed as Ex. Doc. No. 71, H. R., Forty-second Congress, third session. It is very interesting, as it presents in detail a phase of the complications which attend the construction of bridges that will be the least obstruction to navigation. These reports, omitting some of the accompanying documents, are printed in the Annual Report of the Chief of Engineers, 1873, pp. 553–577.

In 1875 the Milwaukee and Saint Paul Railway Company were allowed to proceed in the construction of the bridge at their own location.

GENERAL DESCRIPTION OF REGION ABOUT LA CROSSE.

(See Diagram 11.)

La Crosse is built upon the east bank of the Mississippi, on a sandy terrace, elevated from 10 to 40 feet above the floods. This terrace extends many miles up the valley, being cut through by the La Crosse and Black Rivers, but terminates about 4 miles below the city. At the city this terrace is about 2½ miles wide, and this is the only place where it touches the permanent channel of the river. There is also a similar terrace, of less extent, on the west side of the valley, but the two are separated by about 2 to 2½ miles of intervening bottom-lands, islands, and river. The river rises, from lowest to the highest stages, about 16 feet.

The islands and bottom-lands are of sand and mud, in most places deeply inundated at high water, and many lakes and marshes exist at nearly all times. The distance between the sand terraces (2 to 2½ miles) gives a measure of the general extent of bridging and embankment for the approaches, the relative amounts depending upon different locations. The bed of the river is entirely of sand in this neighborhood, and no borings have been made to reach the rock beneath it. The depth of sand is probably not less, generally, than 70 feet.

The river slope is gentle and the current mild, varying from 2 to 3 miles an hour. The river is divided by islands, so as to nowhere flow in a single channel, and sometimes there are two of the principal of these that are nearly of equal width and depth. The nearest union of all the water in one channel occurs below La Crosse, between the small islands of La Plume and Broken Arrow, a place formerly much used by the Dakotas or Sioux as a crossing-place (*Traverse de Sioux*). This has been so from time immemorial, and here the Southern Minnesota Railroad Company locate their crossing. A large island opposite La Crosse is known as Grand Island, and the city people want a bridge there. A considerable island above this, known as Minnesota Island, across the foot of which the Milwaukee and Saint Paul Railroad Company located their bridge, divides the river nearly equally. Its name indicates that the main low-water channel is or was on the Wisconsin side of it. The law fixing the boundary of the two States makes it the main channel of the river, and the lines of the Minnesota land surveys were extended over this island. It is probable that by artificial works the main low-water channel could be kept permanent on either side of this island.

The distance between the main bluffs bounding the valley is from four to four and a half miles. These bluffs are in the neighborhood of 400 to 450 feet high. They are composed of magnesian limestone of the Silurian epoch, and nearly horizontally stratified. The heights of these bluffs give a good idea of the ascent and descent a railroad line must make in crossing the valley between two points of the interior, east and west of the river.

The low-water channel is at the foot of these bluffs on the west side, about six miles above La Crosse, and again on the west side, about ten miles below, at Brownsville, Minn. These high bluffs bordering the valley make it a matter of some difficulty for a railroad to get from the river-banks up to the level of the high prairie, except along the valley of an affluent to the main river.

On the west side of the river the Southern Minnesota Railroad has a good approach in the valley of Root River, Minnesota, which debouches into the Mississippi a few miles below La Crosse, leading in a westerly direction. The valley of Pine Creek, Minnesota, debouches opposite La Crosse, leading out in a northwesterly direction, and this is said to be the line chosen by the Saint Paul division of the Dubuque and Minnesota Railroad. The valley of the Mississippi itself furnishes good routes for roads leading northwesterly, and both sides are already selected for roads, the left bank being taken for the Milwaukee and Saint Paul Railway.

On the east side of the Mississippi the valley of Black River opens out to the northeast. The valley of La Crosse River, coming into the Mississippi Valley about two and a half miles above La Crosse, furnishes the route for the railroad eastward to Milwaukee. Any other road to the east will probably have to go down the Mississippi Valley in a southeasterly direction till some suitable tributary valley is reached.

SURVEYS.

In October, 1866, a survey of about four miles of river, commencing about two miles above and extending two miles below La Crosse, was made by us. At that time bridges were contemplated but none had been authorized. The river was about 2.5 feet above low-water. The slope per mile was 0.35 foot. This survey commenced near the site since chosen by the Milwaukee and Saint Paul Railroad Company for their bridge.

In September, 1876, we made surveys and examinations at this place while the bridge was in process of construction. The water was two feet above low water. The rise from low to high water is given by the bridge engineers as 14 feet, but this seems too little. The high-water mark of 1859 on Coon's warehouse, in La Crosse, was 13.83 feet above the surface of the water in October, 1866, and as higher waters than that of 1859 have occurred in this part of the river, as determined by marks in the river above, we concluded that the range must be greater, probably as much as 16 feet.

DESCRIPTION OF BRIDGE.

(See Diagram 12.)

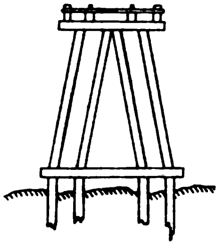
Approaches and arrangement of spans.—Commencing at North La Crosse, there is an embankment 1,420 feet in length to the Black River; then 600 feet of pile trestle to a pivot-draw span; this span is 310 feet over all; then 1,900 feet of trestling to French's Slough; the bents of this trestling are 16 feet apart and rest upon 4 piles sawed off about 3 feet above surface of the ground. French's Slough is now crossed on trestling, but the company propose to put in a 100-feet truss upon stone piers. From French's Slough to the old channel, 2,000 feet, there is trestling; of this distance 1,125 feet is on a 2° curve, which ends 50 feet from the pier on the bank of the "old channel." This old channel is crossed by 5 spans of 148 feet each, total 740 feet; then 650 feet of trestling across Minnesota Island to the bridge, over what is now the main channel of the river; of this distance 593 feet is on a 5° curve. The main channel is crossed by two spans of 164 feet each—one of 250 feet, and a pivot draw of 360 feet. This portion of the bridge is on a straight line, which extends 100 feet beyond the right or west abutment; then comes a 6° curve for 534½ feet, and then 4,340 feet tangent, extending to La Crescent junction; all on the west side of the bridge is trestle. The whole length between main line on east side of river and main line on west side is 13,540 feet; of this distance 1,420 feet is embanked on the east approach, leaving 12,120 feet of bridging and trestling. This trestling the company propose to replace by embankment to as great an extent as the requirements of high-water way will allow.

Grades.—The draw over the Black River is approached on an upgrade of one-half foot in a hundred; the elevation of rail by the railroad levels on the draw is 58 feet. The water's surface at time of survey, September 30, 1876, was 21.4 feet below the rail; the lowest part of the draw was 17.8 feet above the water. After crossing the bridge there is a down-grade of one-half foot to the hundred for 900 feet, descending to 53.5 of the railroad levels; then it is level 1,340 feet, until French's Slough is crossed; then an upgrade for 1,800 feet, where the elevation of 62.5 feet is reached, and this is the level of the rail on the bridge over the "old channel," and across Minnesota Island, and over the present main channel of the river.

Substructure.—Commencing with the trestling in the Black River approach (the trestling rests upon piles sawed off near the surface of the water), the bents are 16 feet apart from centers, except for the last 100 feet before reaching the Black River draw-span, where they are but 12 feet apart. Each end of this draw-span rests upon a pier of three rows of capped piles at right angles with the axis of the bridge. The center pier is of masonry resting on piles. It is 27¼ feet in diameter on top, with a batter of one-half inch, down to one foot below present water's surface, where there is an offset of 6 inches. The top of the masonry is 11 feet 7 inches above present water, and 9 feet 10 inches below top of rail. The draw-span rests, when open, upon three rows of piles, above and below the bridge. Detached ice-breakers are placed above the upper guard-rest, and above the pile trestling. The trestling between the draw-span over Black River and the "old channel" rests upon piles sawed off about 3 feet above the surface of the ground. The bents are 16 feet apart from centers. The piers of the bridge over the "old channel" are six in number. The two standing on the banks are 22 feet long and 5 feet wide on top. The four standing in the "old channel" are 6 feet wide on top under the coping and 22 feet long, with a triangular starling on

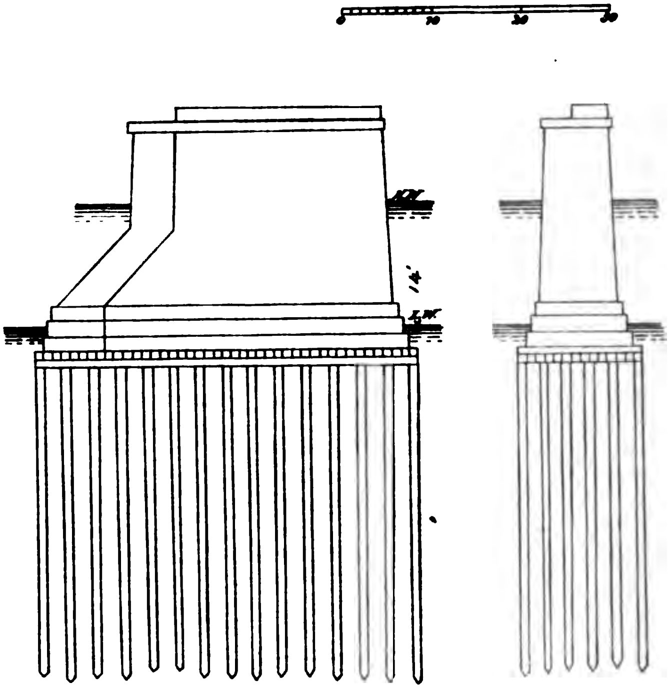
La Crosse, Wis.

TRESTLE BENT.



ELEVATIONS OF PIER 3.

Scale of Feet



AM. PHOTO-LITHO. CO. N.Y. (OSBORNE'S PROCESS.)

the upstream end. The foundation of these piers is a grillage, 2 feet below low water, resting on piles. On this are three heavy courses of stone, making offsets of 6 inches. The cut-water of the starling then begins, and rises with a slope of 1 upon 1. The batter of the pier is 24 upon 1.

The top of the piers was 21 feet 8 inches, and the top of rail on trestle at pier on Minnesota Island 23 feet 6½ inches above the water at time of our survey. This trestle was just built and the rail laid when the measurement was made.

The bents are 14 feet apart from centers. The first pier on bank of the main channel is 21 feet long on top (under coping) and 6 feet wide, with a batter of ½ inch to the foot. This pier has no starling. Commencing at 3 feet below low-water are three courses, each offsetting 6 inches on all sides; under this a grillage of timber of two courses resting upon piles.

The other piers, except the rest-pier, east of draw, are of the same dimensions, except that they have starlings. The starlings are equilateral triangles whose sides equal the width of the pier. From a point 10 feet above low-water the slope of the starling begins, 1 on 1, and is continued down to the first offset course. The east or left rest-pier is 23 feet long on bridge-seat, 27 feet 11¼ inches under coping, and about 38 feet immediately above first offset course. This course is 2 feet above low-water; the bottom of the masonry is 3 feet below low water. (See Diagram Z.) At the time of our examination the shore pier on the island and the first one in the river were the only ones completed; the next pier was in process of construction. The east rest-pier and draw-pier had the piles driven only. The piles had been driven for both guard-rests, and the upper one built. This upper guard-rest is of 12-inch by 12-inch timber; it is 170 feet long and 32 feet wide, with two side compartments 8 feet wide each, and a center space of 16 feet. The outer spaces were to be filled with stone. The bottom of this rest is 9⅓ feet below low-water. The starling commences 1 foot above low-water, with a slope of 1 on 1, which is carried up to 10 feet above low-water. The whole height above low water is 17 feet 4 inches. The pivot-pier is of masonry, and of the following dimensions: At 2½ feet below low water, 33½ feet in diameter; at 10 inches above low water (the top of offset courses) the diameter is 31 feet 3 inches; and at 15⅔ feet above low water (just under the coping), 30 feet; on the top (17 feet 10 inches above low water) the diameter is 31⅓ feet.

The piles in the main channel under the piers were driven by a "Nasmyth" hammer to a depth of about 40 feet below bed of river; those under the other piers were driven by a common pile-driver to a depth of from 20 to 25 feet.

Superstructure.—The superstructure, as far as erected at time of our survey, is as follows: The draw-span over the Black River, 310 feet over all, is all of iron, except the floor-beams, which are wood. It is about 22 feet high at the ends and 30 feet at the center. It has 11 panels each side of the center panel, which is 19 feet. This draw is turned by men with levers. But one of the openings can be used by rafts or steamboats, the right-hand one being obstructed by a shoal above, and by the wharf of a saw-mill immediately below. The draw is but little used by boats, the river being navigable for only a short distance above the bridge. The space above the bridge is used as a winter harbor and repair basin, and large shops are located there. This draw-span was required by a law of the State of Wisconsin. Over the "old channel" there are five spans of iron, built by the American Bridge Company of

Chicago. These spans weigh about 70 tons each. They have each 10 panels. The height of truss is 22 feet. The floor-beams are suspended from the foot of the posts. These trusses seem very light, not quite 1,000 pounds. to the running foot; the ties cross one panel, or what is termed single intersection. This and the railway bridge at Louisiana are the only iron bridges on this river that are built with diagonals of single-panel length.

Accessory works.—The location of this bridge at a point where the river was divided into two nearly equal channels made the closing of the left or "old channel" to the east of Minnesota Island necessary to insure the navigation of the other, where the draw was placed. A dam was built at the head of the island, about 1½ miles above the bridge. It is inclined upstream from the head of the island, and is about 1,600 feet long; the width of the water-way closed is about 900 feet.

The head and shore of the island for a distance of about 3,800 feet have been protected by riprap. At a point about 3,000 feet from the head of the island the water broke through and ran into the "old channel." The difference of level in the two channels being a little over 1½ feet in a distance of 800 feet, gave it a rapid velocity. This opening was closed with brush and riprap. This dam was built in very cold weather in the winter of 1875–'76. The ice was cut on the line adopted for the dam, and a row of piles driven on the lower side. Against these were placed mattresses of brush and hay loaded with stone, and well covered with riprap after it reached the height of a few feet above low water. Although it was a success, it was a difficult and expensive operation. The thermometer being much of the time below zero, the ice formed rapidly in the opening made, so that it was impracticable to work along the whole line at once and cover the whole bottom with a layer and then follow it with successive ones. The work carried on from the ends caused deep scouring in places, and largely increased the amount of material required. The ice-bridge did away with the necessity for boats, but this advantage was more than lost by the trouble the cold and ice gave, and by reason of the short days of winter. The dam withstood the succeeding high water, and in low stages confined all the water to a single channel, and required its enlargement in order to restore the former area of section and velocity. With this requirement suddenly forced upon the the new channel, it became engorged, and its slope and velocity increased. A more rapid movement of the sandy bed resulted, but still the latter motion was slower in effect than might have been expected. The consequence was but a gradual change in line of the deepest water as the sand-bars moved down the stream, and sometimes the situation of the bars was such, with the water drawing directly over them, that it became a matter of difficulty for boats to follow the deep water between the bars. At the time of our examination the conditions were more favorable to navigation than they had been for some time previous.

It would have been more judicious to have waited until the new regimen had been established before building the bridge. It is contrary to good river engineering practice to suddenly close so large a channel at once, as was done in this instance. The proper way is to lay down a layer of mattresses about 2½ to 3 feet thick, weighted to hold them in place, entirely across the channel it is proposed to close. This would exclude but a part of the water, and while forming a receptacle for sand to lodge behind, would force enough water into the other channel to produce a proportionate enlargement. After this object is reached another layer may be put across the channel to be closed, and its effect awaited. Perhaps the next time it might be closed entirely, but if not, the same process should be gradually continued until the end is reached. If the channel to be closed is of considerable length and capacity, layers of mattresses should be used along it at other points than the head.

INFLUENCES OF NAVIGATION.

When our examinations were made, the right draw space was the only one available for either boats or rafts by reason of the existence of a bar extending from near the upper end of the guard-rest to the left bank of the river. The maximum current in this span was as great as 4½ miles per hour.

During the summer the passage of the piers and accessory works had been attended with delay to boats and many accidents to rafts.

The bar on the right-hand side of the channel above the bridge had at one time advanced downstream so far as to leave only a narrow channel between it and the bar immediately above the bridge. The crossing from left to right bank between these bars was nearly at right angles with the channel above, and in running it rafts would sometimes be carried by the current upon the bar below, or upon the upper guard-rest. At the time of our examination there was a channel through the upper bar 6 feet deep, by which the approach to the bridge was nearly direct.

Great irregularities were found in the cross-section at the bridge, the right draw space having a depth of 26 to 28 feet, while in the other spans there was not over 11 feet; and in the sections above and below the bridge, at a distance of 800 to 1,000 feet away, the maximum depth was but 14½ feet, showing a probable scour of not less than 13 feet in this channel at the bridge. In sounding from a short distance above down through this draw opening the bottom appeared very irregular, there being one or more ridges with not more than 15 feet water upon them; these ridges seemed, from the limited examination given, to be covered with stone. This channel was fast increasing in width by undermining and caving of the bank until it was protected by a line of piles and riprap.

The current approached the axis of the bridge at an angle of 15° with the axes of the piers, except near the middle of the right-hand draw opening, where it was nearly direct. Immediately below the lower guard-rest the current sets toward the left bank.

ALTERATIONS TO LESSEN OBSTRUCTIONS TO NAVIGATION.

Whether any such will be needed, and to what extent, can only be found out after the work is completed, and we shall have to await the completion of the enlargement of the single channel before we can judge how the bridge will affect it.

HIGH BRIDGE.

By moving the site of the bridge about one mile above its present location, a high bank on the right side would furnish an approach to a high bridge. The opposite bank would be low. A high bridge at this point, on account of the rise being about 16 feet from low to high water, should be 75 feet above low-water, or 59 feet above high-water.

PRAIRIE DU CHIEN PONTON RAILWAY BRIDGE.

(Open for railway travel April, 1874.)

Authority.—In the act approved July 25, 1866, section 6 provided "for a bridge from Prairie du Chien, Wis., to North McGregor, Iowa, subject to the same conditions" as fixed for the bridge at Quincy. This bridge was never built, probably because the division of the river into two good navigable channels required two draw-bridges.

Peculiar condition.—The river at this point is divided by an island, and is about 1¼ miles in width from shore to shore. Before the building of the bridge, passengers and freight were transferred by ferry which had to go around the head or foot of this island, making the distance from landing to landing nearly 4 miles. The freight cars were transferred on boats built for this purpose. This mode of transfer was slow and expensive when the river was clear, but when the ice began to form, and before it got sufficiently strong to cross upon, was very slow and difficult, and insomuch that sometimes nearly all the rolling stock would be accumulated at this point. Again in the time of the breaking up of the ice in the spring there was delay, though not usually so long as in the fall. To shorten this ferriage a pile-bridge was constructed across the island, and a boat used in each channel. From this time on, a train was run across the island from one channel to the other.

In the winter of 1868 or 1869, after the river had frozen over, piles were driven across both channels and the trains run through without delay until the ice broke up in the following spring, when the ferry was again resorted to. This continued until April 14, 1874, when the first train passed over the present pile and ponton bridge. A bill to legalize this form of bridge was introduced into Congress, and, on reference to the War Department, was reported upon favorably by Col. J. N. Macomb, United States Engineers, May 6, 1874. (See Annual Report of Chief of Engineers, for 1874, Part I, pages 680–682.) The act was passed; approved June 6, 1874.

DESCRIPTION OF RIVER AND VALLEY AT THE LOCALITY.

(See Diagram 13.)

The right bank of the Mississippi River is high, rocky, and steep from the mouth of the Yellow River, 3 miles above North McGregor, to about 3 miles below, presenting no practicable approaches for a railroad from the west except at the towns of North and South McGregor. Opposite the town of South McGregor the river is all in one channel. The railroad, as first built to Prairie du Chien, terminated opposite, and here was the easiest place to build a bridge. For some reason the railroad changed the depot to about 2 miles up river to North Prairie du Chien and opposite North McGregor. Between this new terminus in Prairie du Chien and North McGregor the river is divided into two navigable channels by a large island, extending 3 miles up and down the river. The width across here, including the space occupied by the island, is about 1¼ miles. At the time of ordinary high-water the width is about the same, but the island is completely submerged. Prairie du Chien is situated on a sand terrace, from which it derives its name, most of which is above overflow, the higher parts as much as 40 or 50 feet. Back of this sand terrace are high rocky bluffs, the distance between the bluffs being about 2½ miles. The current in this part of the river is gentle. The rise from low to high water is 22 feet. The bed of the river is sand, mud, and shells, and subject to but little change. The lower part of the island, over which the bridge crosses, is nearly all occupied by a lake, with only a narrow strip of land between it and the channels.

SURVEYS.

In October, 1866, we made a survey of the river from the head of this island to and including the mouth of the Wisconsin River, a distance of 7 miles. This survey was of both channels, and covered all the river where it was feasible for a railroad to reach it from the west, to connect with that already built to Prairie du Chien. No location for a bridge having then been determined upon, the survey was general in its character. The slope and volume were measured, and soundings were taken throughout the whole distance.

In October, 1876, after the completion of the ponton bridge, a survey and observations for the direction of the current were made, the water at that time being about 6 feet above low-water. This survey was confined to the immediate vicinity of the present structure.

DESCRIPTION OF THE BRIDGE.

(See Diagram 14.)

In this bridge the approaches and fixed portions across the channels and islands are of piles. The openings in each channel, left for passing vessels and rafts, are filled by strong deck-scows called pontons, swung into position for the passage of trains, and left open at all other times. These pontons lie athwart the stream, and not like pontons in ordinary military bridges in the direction of the stream. The ponton in the last channel is made by uniting three ordinary transfer-scows, rigidly, end to end, each 131 feet long, 24 feet wide, and 6 feet deep, making, together, a length of 393 feet. The ponton in the west channel is a single-deck scow, specially constructed, 408 feet long, 28 feet beam, and 6 feet depth. The ponton in each channel, when in position in line with the piling, stands at an angle with the general direction of the current of about 55°. The upstream end of the ponton is made fast to a dolphin (a clump of piles united together) in such a manner as to allow it to swing freely. The downstream end is held in position by being fastened to another dolphin. On the downstream end of the ponton is placed a small steam-engine, provided with a drum around which a chain is passed. The ends of this chain are fastened to dolphins or groups of piles, one above the ponton when closed and the other at the end of the ponton when open. When it is desired to open the bridge the pawl is thrown off of the drum and the current opens it in about one minute, the chain rendering around the drum. When it is to be closed, the engine is started and the drum turned in the opposite direction, and the ponton is brought into position in the bridge; this requires from 3 to 5 minutes. On the east ponton the rails are laid on a longitudinal stringer on the deck, and there is no appliance for raising and lowering the track, so as to suit different stages of water. Small changes in the height of water are provided for by short adjustable sections of track at each end, which serve as inclined planes, connecting the boat and the stationary track. This arrangement answers for but a limited change in the height of water. To meet the change in level, from high to low water, it was necessary to build two approaches, one for high-water and one for low-water, each about 2,100 feet long, the low-water approach being submerged in time of high-water.

In the west or McGregor channel the ponton is so built as to allow of an adjustment for different stages of water, so that one approach serves for all stages. In this boat are two trusses running the whole length. These trusses rest upon the bottom of the boat and are 14 feet from outside to outside. They rise about 5 feet above the deck of the boat. The track is placed between these trusses and adjusted for the different stages of water by being blocked up as the water falls, and by the blocking being removed when the water rises. This ponton is operated in the same manner as that in the east channel, except that the steam-engine is placed in a flat-boat 48 feet long and 16 feet wide, which is attached to the lower side near the downstream end of the ponton.

The west channel, being the most direct, and protected by the high bluffs from winds, is the only one used by the rafts going below this point. To facilitate their passage through the bridge, and to turn the floating ice into the opening and keep it from the pile-trestling approaches, a set of dolphins have been driven above the bridge in lines running from the opening to either bank at a distance of about 1,000 feet on east bank and 500 feet on west bank. These dolphins consist of 12 or a less number of piles driven in a close group, held together by being waled near their heads. On the channel sides of these dolphins (extending 250 feet above the bridge on the west side, and 500 feet on the island side) there is a floating boom held to them by chains. These booms, near the bridge, are composed of four sticks, laid side by side; a little above, of three sticks, and then of two sticks, to their upper end.

In the east channel the only protection against ice is in dolphins at each end of the openings, and twelve dolphins in a line to the shore of the island from the west side of the opening. All of these twelve but the one nearest the island, were broken down last spring by the ice. These dolphins, while of sufficient strength to withstand any shock that they will be likely to receive, except from ice, are wholly inadequate as ice-breakers. It is probable that no ice-breaker constructed of piles alone would successfully resist the pressure of such ice-fields as they would be subjected to in this part of the Mississippi.

INFLUENCE UPON NAVIGATION.

This bridge is practically no obstruction to steamboat navigation. The current, at the time of our examinations, when the water was about 6 feet above extreme low, was but 1½ miles per hour in the east or Prairie du Chien channel, and 2 miles per hour in the west or McGregor channel, down which the rafts pass, the opening being sufficient for the largest ones.

The booms above aid to direct the rafts into the opening when they are but a little out of direction, or when they strike at only a small angle, although they are sometimes considerably broken even then. If in any way the raft gets such a direction as to strike it at a large angle, it will be much broken up. Experience here shows that fixed sheer-booms cannot guide rafts without subjecting them to injury.

The opening in the east channel is 393 feet on line of ponton, but the available distance is but 345 feet between the two dolphins at the ends of the ponton. The clear distance at right angles with general direction of the current is this distance into the sine of the angle of 58° which it makes with the direction of the current—sine 58° into 345=293 feet as the available opening in east channel between the dolphins. The clear opening in the west or McGregor channel is the distance along the line of the ponton into the sine which it makes with the general direction of the current—sine 55° into 408 = 334 feet clear opening at right angles to the general direction of the current. These pontons are removed in winter, and the openings filled with piling, making a complete pile-bridge, until the river opens in the spring.

GENERAL REMARKS.

This novel bridge was designed and constructed by Mr. John Lawler, of Prairie du Chien, Wis., to meet the practical wants of the transfer at this locality. He has also built one at Stillwater, Minn., across Saint Croix River Lake. It appears well adapted to places like these where the current is not strong.

On Lake Champlain is a similar bridge with a ponton draw 300 feet long, 30 feet wide, 12 feet high, draught 2 feet. It is connected by hinges with a pier, and is swung by means of chains. (See Van Nostrand, vol. vi, p. 221, February, 1872.)

One of the difficulties in the application of this kind of bridge is the change in level from high to low water, which in these localities is about 20 feet. Floating ice is another difficulty attending its use, but at these places the river closes and opens with so brief an interval of moving ice that the inconvenience is not long felt, although it is during its continuance the greatest trial to which the bridge and its management are subjected.

There appears no reason why the pontons could not be made in the ordinary manner of several boats lying, when in position, in the direction of the current and supporting a continuous truss on which to receive the passing trains. Such an arrangement could be made to give greater lateral stability with the same flotation than the method used by Mr. Lawler, and while in position small cakes of floating ice and drift of ordinary kind could readily pass.

HIGH BRIDGE.

A high bridge at this place would have to be 77 feet above low-water. It would have high ground for the McGregor approach, and on the Prairie du Chien side the ground is above high-water. It would have to have high, long spans over both channels, and it would make a very long, expensive bridge. The location at South McGregor would avoid this, the river there being all in one channel. Another good location for a bridge would be found at the mouth of the Yellow River. The valley of this stream would furnish a location for a railroad with easy grades and good alignment, both of which are wanting in the McGregor ravines.

DUBUQUE RAILWAY DRAW-BRIDGE.

(Opened for travel December, 1868.)

Authority.—This bridge was built in 1868 by the Dubuque and Dunleith Bridge Company, under act of Congress approved July 25, 1866.

DESCRIPTION OF THE RIVER AND VALLEY AT THE LOCALITY.

(See Diagram 15.)

It crosses the river from Dunleith, Ill., to Dubuque, Iowa. The Mississippi at this point is about 1,700 feet wide between the banks; above, for 2,000 feet, it is about 1,300 feet wide. Immediately below the bridge the width increases to upward of 2,000 feet.

The high-water width of the river is about 4,000 feet. The left bank is high and rocky. An attempt was made, between the years 1853 and 1857, to confine the river at Dubuque between its low-water banks, in all stages, by building a levee along the right bank from a point just above the site of the bridge to the lower end of the city of Dubuque. Some of the streets of the city were extended out to it, and through these streets small openings were left to allow for the drainage of the city and bottom land. Through the low land thus leveed ran the outlet of Lake Peosta. This lake is of considerable extent even at low water. It receives the drainage of a considerable section, and at times of high water becomes a part of the Mississippi itself; the water coming into it over the low bottom land between it and Eagle Bluff, 3 miles above the site of the bridge. There is a saw-mill located on this lake, the logs for which are brought in from above at time of high water. The openings left in the street extensions were too small to carry off the water brought in through this lake, and a portion of the levee was carried away below, and another opening made above Seventh street extension, at the first high water succeeding the completion of these improvements. This latter opening, called Seventh street slough, is considerably used by the lumbermen to lay up lumber rafts until they are ready to haul out the lumber. The works of embankment in Dubuque greatly contract the natural water-way at high water at the site where the bridge was afterward built, and consequently at this stage the flood-water pouring into the narrowed water-course from the right side above the bridge produces a marked change in the course of the current of the main stream from what it is in ordinary and low stages. No attempt has since been made to repair the levee or close the openings in the dikes, and this would be impracticable unless the work of leveeing were carried up to Eagle Bluff, excluding the river water from Lake Peosta.

SURVEYS.

A survey of about 4 miles of river in this vicinity was made by us in September, 1866. The location of the bridge had not been fixed, so no special examinations were made at any particular locality. This survey showed that the river had a good navigable depth, small slope, 0.25 foot to the mile, and consequently slow current, it being in this respect a good point to bridge the river. An examination was made in 1868 at time of low water when the bridge was nearly completed, and another in 1869 when the water was high. The rise from low to high water at this place is 22 feet.

DESCRIPTION OF BRIDGE.

(See Diagram 16.)

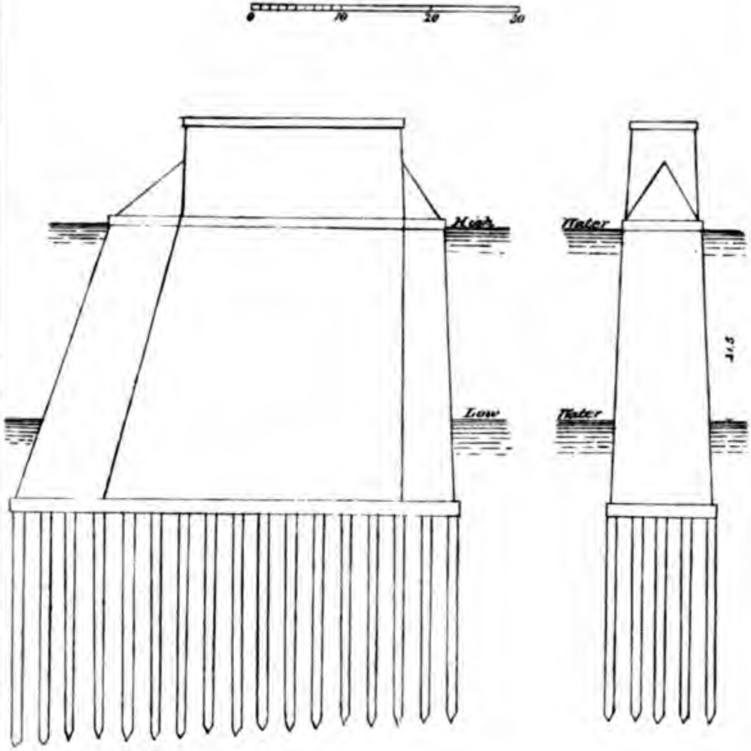
Approaches and arrangement of spans.—The bridge approach from the Iowa side is over bottom land or trestling, for a distance of 2,400; feet a portion of this distance is on a curve of about 1,400 feet radius. The first pier is placed upon the old levee at a point 125 feet back from the usual low-water shore line. The next pier was built in the river at what at the time of our examination was a dry sand-bar, the river being 3¾ feet above extreme low-water. The other piers stand in the water. The spans commencing at the Iowa shore are, first, four of 225 feet from centers; then one of 250 feet from centers; then a draw-span, 360 feet over all, with clear openings of 160 feet; then a span of 250 feet reaching to the Illinois abutment. One hundred and fifty feet from this abutment is the entrance to a tunnel 835 feet in length. This tunnel is 22

Warren's Report Bridging Mississippi River. *Diagram A'.*

Dubuque, Iowa.

ELEVATIONS OF PIER 4.

Scale of Feet



AM. PHOTO-LITHO. CO. N. Y. (OSBORNE'S PROCESS.)

feet wide, 18 feet high, and is on a curve of about 625 feet radius. This bridge takes up only so much of the water-way as is occupied by the piers, the full width being allowed for the passage of flood-waters.

Substructure.—The masonry of the piers rests upon grillages placed upon piles which are sawed off about 10 feet below low water, where the water was deep enough. The dimensions of pier No. 4 (see Diagram A′), counting from the one on Dubuque levee, are as follows: 24 feet long on the bridge-seat, and 7 feet wide, with a batter of one-half inch to the foot vertical. At a point about 12 feet below the bridge-seat there is a band course projecting 4 inches; below this course the upper end is finished as a starling, with a slope of 4 inches to the foot on the nose. The horizontal sections of these starlings are equilateral triangles, with the exposed sides hammer-dressed. The lower end of the pier below the band course has a semicircular horizontal section. Above the band course both ends are finished as sections of cones running about halfway up to the bridge-seat. The bottom of the masonry in deep water is about 10 feet below extreme low water. At this level the pier is about 50 feet long and 12 feet wide.

Riprap was placed about all of the piles to an extent deemed sufficient to protect them against scour. The draw-rests are timber cribs built above high water, with compartments filled with riprap. These cribs were placed upon the bottom of the river and protected by riprap. At the next high-water, sand scoured out beneath and let the riprap down, and when the water fell the sand was deposited over the riprap. Additional stone was put in of 1½ cubic yards in size.

Superstructure.—The superstructure is of iron, built by the Keystone Bridge Company, of Pittsburgh, Pa. All the parts of the draw are of wrought iron; in the other spans cast iron is used for the upper chord and the head and foot of the posts. The draw is opened and closed by a small engine resting upon the drum of the turn-table; it is also provided with apparatus for turning by hand. The engine drives a horizontal shaft, geared to a vertical shaft that turns the draw by cogs around the perimeter of the drum. In attempting to open this draw-span in a high wind the engine proved of too little power to control it. In its course it struck the plates on the rest-piers and tore them off, and displaced part of the coping of the piers. The engineer attempted to stop the draw by reversing the motion of the vertical shaft, but it was torn from its fastenings to the drum. This occurred in the first year after the bridge was opened. It was then proposed to replace this engine with one of more power, but I do not know what has been done.

INFLUENCE UPON NAVIGATION.

Our examination of this bridge in November, 1868, was when the water was 3.7 feet above extreme low water, and its maximum velocity about 2 miles per hour. The general direction of the current through the east draw-opening was nearly parallel with the axes of the piers. In the first span to the right of the draw the currents set toward the right at an angle of about 10° with the axes of the piers. This span is generally used by rafts. At the time of our examination in 1869 the water was 13.2 feet above extreme low water. The maximum velocity was through the draw-spans, and was about 3 miles per hour. The general direction of the current through the east draw-opening, at that time, made an angle of about 5° with the axes of the piers. Through the west draw-opening the general drection taken by floats was nearly parallel with the axes of the piers. The change in direction between low water at the time our first observations were made, and at high-water when our second observations were made, was considerable. But at each stage one of the draw-openings was available, with current direct through it. At low-water the left draw-opening was the better, and at high water the right opening was the easier to run. From the right bank, at time of high water, the current sets toward the center of the bridge, so that floats put in opposite the span next Dubuque, 1,000 to 1,500 feet above the bridge, passed through the fourth span from the Iowa shore at an angle of 25° with the axes of the piers. This was caused by the current setting out of Seventh street slough immediately above the bridge. The current through the long span next to the right draw-opening was practically parallel with the axes of the piers. The span next the draw on the left or Illinois side cannot be used for rafts floating with the current on account of a bank built out, and formerly used as a transfer landing, about 400 feet above the bridge. If, from this point, a line be drawn in the direction of the current (nearly parallel with the piers), it will cut off 150 feet of this span, and this is practically equivalent to reducing the width for raft navigation by that amount, which renders the whole useless. This span, if its full width had been made available to rafts, would have been very useful.

The passage-way provided for steamboats is as good as a draw-bridge at the site permits, unless by proper rectification of the Illinois shore it had been made so that one draw-opening could be placed next to it. This would have been especially desirable at this point, which is one where the wind is very troublesome to boats passing the bridge. It would have brought the 250-feet span, which is on the right of the draw-opening, 100 feet nearer the center of the stream, and rendered its use by rafts more easy.

ALTERATIONS TO LESSEN OBSTRUCTIONS TO NAVIGATION.

Sheer-booms.—The Board of Engineers recommended that a sheer-boom 1,200 feet long be placed with its lower end abutting against the pier on the right of the Iowa 250-feet span, and to extend upstream on prolongation of the axis of the pier, so that it can be swung to sheer rafts into the right raft-span, or into the right draw-span. Those representing the raft interest before this Board asked for booms on other piers, but as they would interfere with the passage of the bridge by steamboats they were not recommended.

Lengthening of left rest-pier.—This pier should be extended upstream 800 feet in the direction of the current. This extension should be 4 feet above high-water, and built of timber with its sides smoothly planked. If this were built boats could "round to" and drop through the bridge alongside of it, avoiding the now frequent delays on account of darkness or high winds.

HIGH BRIDGE.

This place is one of the most favorable for a high bridge on this part of the river. The left bank is high close to the shore, and high land opposite is but one mile distant. The provisions for clear headway of 55 feet above high water, which is 77 feet above low water, would give an opportunity for all boats to pass under it that can pass the bridge at Saint Louis. (See Chapter III.)

PROPOSED PONTON BRIDGE AT DUBUQUE, IOWA.

An act of Congress approved March 3, 1875, authorized the construction of a pile and ponton bridge across the Mississippi River at or near the city of Dubuque, Iowa. The proposed plan and location were submitted to the Secretary of War. A Board of Engineers—Col. J. N. Macomb, president—was convened to consider and report upon them. This board objected to the first and second locations, which were near the present bridge, but approved of the third, which was at Eagle Bluff, 2½ miles above. (See Annual Report of the Chief of Engineers for 1876, Part II, pp. 308, 313.)

This bridge has not been built.

CLINTON RAILWAY DRAW-BRIDGE.

(Opened for railway travel in January, 1865.)

Authority.—This bridge was built by the Albany Bridge Company, under authority of the legislatures of the States of Illinois and Iowa. The portion over the east channel and Little Rock Island was built and in operation some time previous to the building of that portion over the west channel, the transfer over this being made by ferry. It was declared a post-route by act of Congress approved February 27, 1867.

DESCRIPTION OF THE RIVER AND VALLEY AT THE LOCALITY.

(See Diagram 17.)

In connection with this bridge, we shall consider the question of a high bridge at Fulton and Lyons, about 2½ miles up the river, and our description will therefore embrace that locality.

The high ground at Fulton, on the Illinois side, extends only about a mile along the river. The river here is about 3,500 feet wide, and all confined to one channel. About one mile below the high ground the bank of the Illinois side or left bank is composed of a low stratum of lime-rock for a short distance, and opposite this the river at low water is reduced to a width of 2,400 feet, part of which is occupied by a dry sand-bar. This place is about a mile above the bridge, and on many accounts presents a good site for a bridge (although the banks are not above overflow) because the deep water is constantly next the rocky shore. At the site of the bridge the water-way is divided by Little Rock Island. The main channel is on the right or Iowa side of this island, and does not change. The island is composed of stratified lime-rock, a little elevated above ordinary overflow. Between the island and the left bank the water-way is shoal, and much of it occupied at low-water with dry sand-bars and willow-islands. The main bank on the Illinois side is alluvial, and subject to overflow. On the Iowa side it is rock in place, but not above extreme high-water.

Little Rock Island is in the jurisdiction of the State of Illinois, the middle of the west channel being the dividing line between the States of Illinois and Iowa.

The width of the valley submerged at high water is about 2 miles. The slope of the water is about 0.27 feet per mile at low water. The current is gentle, being 1¾ miles per hour when the water is 2.5 feet above low water. With the water 10.7 feet above low water it is about 3 miles per hour in the main or Iowa channel. The rise from low to high water is about 19 feet.

SURVEYS MADE.

A survey of the Mississippi at this bridge was made by me in October, 1866, at a time of ordinary low water, and all the information that could be obtained at this stage of water was secured. Both banks were meandered from Fulton and Lyons down about one mile below Clinton, the river sounded, and current observations taken at the bridge. Current observations were again made here in May, 1867, at time of high water, and again in November, 1868, when the water was low, at the time of the rebuilding of that portion over the east channel.

DESCRIPTION OF BRIDGE.

(See Diagram 18.)

Commencing on the left or Illinois shore, there is 1,390 feet of wooden trestling in the approach to the bank of the river; then there were at first 7 spans of wooden trusses, each 200 feet long; then a causeway 583 feet long across Little Rock Island to the Iowa channel. The Illinois channel thus bridged was crossed at an angle of 74° with the general direction of the channel, so that these spans of 200 feet from centers were practically narrowed to about 190 feet, measured at right angles to the current, and this was decreased by the width of piers and protection of riprap to 160 feet. The riprap protection was raised to about 3 feet above low water; the available width above this stage was practically about 180 feet. The span next to the Illinois shore, the one used by rafts, had this width available for all stages above 3 feet above low-water. The headway at time of high water was about 8 feet under these spans. At the time of our survey, in 1866, this bridge was in very bad condition, the piers, built with a core of concrete, were cracked in several places, and to support the spans temporarily various devices had been resorted to. The trusses, which were of that pattern known as McCallum's, were decayed in many parts, and a large number of the diagonals were split and broomed where they abutted against the angle blocks.

In 1868 and 1869 this part of the bridge was entirely rebuilt; the first span next to the Illinois shore was replaced by an iron truss; the remaining portion, 1,200 feet to the abutment on Little Rock Island, was replaced by 8 iron spans of 150 feet each; the new piers were smaller, 9 feet wide on top, of masonry, resting upon piles. The 200-foot span and the two adjoining 150-foot spans were built by the American Bridge Company, of Chicago, on the Post pattern. The next two spans were built by the Detroit Bridge Company, Detroit, Mich.; the next two, by the Phœnixville Bridge Company, of Phœnixville, Pa.; the next two, by the Keystone Bridge Company, of Pittsburgh, Pa. The last six are of the Pratt truss pattern.

The bridge over the Iowa channel, built in 1864-'65, consists (commencing at Little Rock Island) of one span 174 feet and 200 feet of wood; then a pivot draw-span of iron (Bollman) 300 feet over all, with an opening on the east side of pivot-pier of 119 feet at low-water, and one of 128 feet on the west side; then a span of 174 feet to abutment on the Iowa shore (this is of wood); then a short piece of enbankment.

Substructure.—The piers in the east channel, before referred to, are of masonry, resting on a grillage, which rests upon piles sawed off below low-water. The pivot-pier and guard-rests are combined in one large crib about 400 feet long and 35 feet wide. The left rest-pier is also a crib, filled with stone, 140 feet long and 25 feet wide. The excess in width of these cribs over what would be proper masonry piers is taken from the clear openings of the draw-span. The right rest-pier is of masonry; this opening is 128 feet, while the left opening is but 119 feet. The lowest part of the draw-span is 66 feet above high water. The draw is turned by an engine placed on the truss above the roadway. This was the first draw on the river turned by steam-power.

INFLUENCE UPON NAVIGATION.

Steamboats.—From the time of the opening of navigation, March, 1865, considerable delays were experienced by inability to pass it in time of high winds and dark nights. Vessels were compelled to wait during the prevalence of a high wind sometimes as long as two days at a time. Damages to a considerable extent were suffered in passing the bridge, and, in consequence of these and the injurious delays, suits were instituted or threatened against the bridge company.

The effect of this bridge upon navigation is stated in my letter to the chairman of the Senate Committee on Post-Offices and Post-Roads, dated February 5, 1867, which appears in Chapter V of this report. The subsequent examination made at high-water showed that the direction of the current was not essentially different from that at low water, but that the eddy above the bridge near the west shore was much larger and stronger in high water, making the approach to and passage through the draw-opening more difficult.

Several steam saw-mills have been erected on the right bank below the bridge, which, like all mills or furnaces, make at times dense smoke and bright lights, that greatly interfere with the safe navigation of the river in their vicinity, and add to the difficulties in the passage of the bridge.

The difficulties which steamboats encounter in passing this bridge, appertaining especially to it, may be summed up as follows: the narrow draw-opening, 119 feet in the clear; the eddy above the bridge, which makes the course of the current to continually change, and the curve in the main channel where the bridge crosses. These are sufficient to prevent steamboats passing in time of high winds, to which this part of the river is very liable, and in dark nights and thick weather, the effect of which is intensified by the mills located near it.

Rafts.—This bridge is now a greater obstruction to the passage of rafts than it was at the time it was legalized in 1867, because of the change which has taken place in the method of rafting. Formerly the rafts were all managed by men using large sweeps, and the passing under the low bridge across the Illinois channel did not interfere with the control of the raft, but now the larger number of the rafts are managed by means of small steamboats, and they cannot pass under the bridge. The raft has to be dropped near the bridge in the Illinois channel, and the steamboat goes around the head of the island and passes through the draw-opening in the bridge over the Iowa channel. The bridge over this channel does not furnish suitable openings for the passage of rafts in its present state, though near low water the rafts are sometimes separated into smaller parts and dropped through this channel by the boats.

The spaces between the piers of the bridge over the Illinois channel are not sufficient for rafts, for which this is the usual channel.

The difficulties attending the passage of this bridge by rafts are set forth in detail in the report of the Board of Engineers on sheer-booms, dated Saint Louis, Mo., February 2, 1877. (See Annual Report Chief of Engineers for 1877, vol. 1, p. 817.)

ALTERATIONS TO LESSEN OBSTRUCTIONS TO NAVIGATION.

Although it is probable that an entirely new and different bridge will be required to meet the wants of navigation, if the principle is to be carried out which was enunciated in the report of the House committee in 1858, of which the Hon. E. B. Washburne was chairman, "that any bridge is a *material obstruction* which is susceptible of being essentially improved," still there are a number of changes that can be made in the present structure that will make it less of an injury to navigation than it now is.

Sheer-booms.—The Board of Engineers upon sheer-booms, to facilitate the passage of rafts, recommended that a fender be built along the bank above the bridge over the Illinois channel to prevent rafts being drawn into the timber on the bottom at time of high water; that a fixed boom be placed from the upper end of the pivot-rest in prolongation of its east side to the shore above, and that another fixed boom be placed from head of the pier east of the first span east of draw to the head of Little Rock Island. These booms are to be so constructed as not to interfere with steamboat navigation, and it was thought that the boom running from the upper end of the draw-rest to the Iowa shore would facilitate the passage of the bridge by boats.

Straightening the channel.—A further improvement, and one particularly desirable in the present arrangement of the draw-spans, would be cutting off the point of rock above the bridge on the west bank, and filling out the hollow of the bend below so as to destroy the eddy that now makes the passage of the draw difficult. To cut off about 170 feet of the point down to 6 feet depth at low-water requires the removal of about 32,000 cubic yards of rock. The material excavated could be used in making a new bank in the bend below in prolongation of the west rest-pier. This it is believed would make the west draw-opening available when the obstructions placed below it by mill-owners and others are removed, and make unnecessary the sheer-boom to the Iowa shore recommended by the Board of Engineers.

Rebuilding east rest-pier.—This could be done by removing it down to 6 feet below low water, and replacing it by a stone pier of the usual dimensions, which would add about 10 feet to the width of the east draw-opening. This could be done without interrupting travel over the bridge, and without great expense.

Building new draw with wider openings.—A much greater improvement would be to remove the present draw and the fixed span next east of it, and replace them by a draw having openings of 160 feet in the clear, the same width as has been required in the other bridges on this part of the river, and put a fixed span over the present west draw-opening. To do this would require building a new pivot-pier east of and alongside of the east rest-pier, and a new east rest-pier. This can be done without interrupting navigation, and with but little interruption to the travel over the bridge. This change would make this bridge as good for navigation as any draw-bridge on the river, and would do away with the necessity for the previously suggested changes.

As all of the spans over the Iowa channel, except the draw, are of wood, they must soon be rebuilt; and the piers also are of such nature as to require rebuilding before many years.

HIGH BRIDGE.

At this place a continuous bridge should be about 58 feet above high water, or 77 feet above low water, the natural location for which is at Fulton or Lyons.

PROPOSED BRIDGE AT CLINTON, IOWA.

The act approved April 1, 1872, authorized the Chicago and Quincy Railroad Company to build a bridge at this place, and provided in section 4 that it should be available to all railroads desiring to use it, on such term and conditions as might be prescribed by the Secretary of War. Section 5 made the control of the Secretary of War over this bridge greater than had been defined in any previous act, and defined the reserved authority of Congress in compelling future modifications, if required by the interest of navigation.

The act of Congress approved June 4, 1872, made these requirements applicable to all bridges to be constructed thereafter across the Mississippi River under any act of Congress. These provisions are copied in full in this report in giving an account of the bridge at La Crosse, Wis.

Section 4 of the act approved June 6, 1874, provided that the bridge authorized to be erected across the Mississippi River at the town of Clinton, Iowa, by act approved April 1, 1872, "may be constructed and maintained as a pile and ponton bridge," and on September 29, 1874, the Mississippi Union Bridge Company submitted the plan to the Secretary of War. The Chief of Engineers, on being directed to report upon it, submitted the matter to a Board of Engineers of which Col. J. N. Macomb was president. The Board reported on the 8th of October, 1874. (See Annual Report of the Chief of Engineers for 1875, Part II, pp. 682–684.)

The Board recommended some minor modifications in the proposed bridge, but it has not yet been built.

THE NEW ROCK ISLAND BRIDGE.

(Tested May 8, 1872; opened for railroad travel October 8, 1872.)

This bridge, built by the United States (partly at the expense of the railroad company), presents an anomalous case, and, as far as it is a precedent, deserves more notice in this report than any other. Its location and general design were controlled by a number of important requirements, all of which were known, and being built under officers of the government, there is no consideration which influences the present form of this structure that may not be fully and positively stated. Such is not the case with bridges built by private corporations, where it is impossible to know what relative value was given to considerations of a public and general or of a private and local nature. We will therefore begin with an account of the first steps toward its construction.

PRELIMINARY STEPS.

The old bridge having been shown to be a serious and unnecessary obstruction to navigation, Congress, by act approved June 27, 1866, to establish an arsenal, &c., authorized the preliminary steps to building a new bridge and removing the old one. The questions with regard to the change of the railroad were referred by instructions from the Chief of Ordnance (General Alexander B. Dyer), September 21, 1866, to the commissioners appointed under the acts of April 14, 1864, and June 27, 1866, whose duty was to ascertain the true value of the lands and property rightfully owned by those who would have to be dispossessed in adapting the island to the use of an arsenal. This commission was directed, after hearing the parties in interest and taking the necessary testimony—

> To suggest the proper change in the location of the railroad and bridge, and the kind of wagon-road that should be established, and the kind of aid that should fairly and equitably be granted toward effecting these objects. * * * It is essential that the new location of the railroad should be made on the lower end of the island, as laid down on a plat to be furnished by the commanding officer of Rock Island Arsenal (General T. J. Rodman).

The location, as thus laid down, was nearly that on which the new bridge was built, and its adaptability to the wants of the railroad company indicates that their views were consulted in making it. It was arranged for two spans 375 feet each from end to end over the main channel, with bottom chord 50 feet above high water. The rise from low-water to high water was set down as 16 feet, so the gorge high water about 5 feet higher, occurring sometimes at the breaking up of the ice, was not considered. The trusses each side were to be deck-trusses, and provided for an inclination of the rails in reaching the higher spans. Alongside the trusses making the railroad approaches to the high spans were other trusses for the wagon-way, allowing of more inclination for the highway than for the railway, but both roadways crossed the high spans on the same grade. This commission consisted of Maj. Gen. J. M. Schofield, Mr. (General) James Barnes, Mr. Selden, and Mr. Church. Their report to the Chief of Ordnance is dated February 4, 1867. It was forwarded by the Chief of Ordnance with recommendations and suggestions February 8, 1867, and is printed as Senate Ex. Doc. No. 27, Thirty-ninth Congress, second session. During the investigations of the commission, they obtained from Mr. E. H. Johnson, the chief engineer of the Chicago, Rock Island and Pacific Railroad, an estimate of the cost of such a bridge as General Rodman proposed, with the substitution of high spans of 250 feet from centers of piers, instead of 375 feet (the wagon-way to be 17 feet wide and the railroad to have a single track), to cost $1,671,241.81. The commission also obtained an estimate of the cost of a low draw-bridge with the wagon-road above the other, with the provisions regarding the position of piers in the direction of the current, and the position and dimension of spans, provided for in the law for the Quincy bridge. The total cost of this was estimated at $1,296,292.11, and of this sum $1,046,317.58 was for the part over the main river, connecting Rock Island with Davenport. (See Annual Report Chief of Engineers of 1869, pp. 194–199.) The railroad company submitted a proposition setting forth the share of the expense it would take in making the change. When this proposition was afterward considered by the commission, the ordnance officers objected to the width of the wagon-way proposed, which was only 17 feet; and it was thought a much wider wagon-way was necessary, say 26 feet. The railroad company then suggested that the increased width would admit of the railroad being a double track. When this point was reached the estimates were sent for revision to Mr. Johnson, who thought there was no reason to change his first estimate of cost. It is surprising that such a view should have been entertained. I came in charge in 1869 and made an estimate of the cost of the enlarged bridge, allowing the same prices, and found it would be $1,785,142.67 from Rock Island to Davenport, and including the bridge between the island and Illinois, $2,121,526.82. (See Annual Report Chief of Engineers for 1869, pp. 194–199.) Without referring to cost, however, the commission recommended the proposition of the Chicago, Rock Island and Pacific Railroad

Company (their assent to the foregoing modification for a wide roadway being duly certified to).

The essential features in the question of bridging as agreed upon are as follows:

> The government to build over the main channel of the river an iron draw-bridge in accordance with the conditions prescribed in the act of Congress of July 25, 1866, the frame to be of proper breadth for a double track; the wagon-way to be placed high enough to leave the lower chord for a railroad-track; the government to give the company the right of way across this bridge and across the island upon the payment of half the cost of superstructure.

The Chief of Ordnance, in making his report to the Secretary of War, submitting the report and recommendations of the commission, said:

> If the bridge is to be built by the government as recommended by the commission, an additional appropriation of $1,000,000 is requested, and it is desirable that it shall be made before the end of the present session.

The words "additional appropriation" undoubtedly referred to an appropriation in addition to estimates previously submitted. It could in no way be regarded as a statement of the estimated final cost of the bridge, as it was afterward mistaken to be, the mistake causing a serious obstacle eventually to getting to work on the bridge.

In the act for the support of the Army, approved March 2, 1867, $200,000 was appropriated towards building the new bridge, according to the recommendation of the Chief of Ordnance. This recommendation was, more properly speaking, that of the commission. The Chief of Ordnance somewhat qualified his approval, and thought the proposal liberal on the part of the United States, and too much so if the railroad company had not already a right of way. The act required, however, the execution of certain papers binding the railroad company to certain conditions, in regard to future preservation and repair, ownership, use, &c., which the company was found unwilling to accede to, and as the act was not compulsory the commencement of the bridge was stopped.

The Chief of Ordnance says in his report dated October 19, 1867:

> As it is doubtful whether the guarantee which the company is willing to give would fulfill the requirements exacted by Congress of the company in making the appropriation, I would respectfully recommend that the subject be brought to the notice of Congress for such action as may be considered necessary and proper.

A joint resolution was framed to meet the case and was approved July 20, 1868, which gave specific authority to the Secretary of War to allow sixty days after its passage for the railroad company to file an agreement in accordance with it, and if not filed then, he should direct the removal of the existing bridge and proceed with constructing the new one, which the railroad company should not have the use of until it had agreed to and complied with the provisions required of them. This joint resolution contained a proviso that "in no case shall the expenditure on the part of the United States exceed $1,000,000." At the end of section 2 are the words, "all acts or parts of acts inconsistent with these resolutions are hereby repealed." In the complications which followed a due regard was not had to this repeal of parts of former acts inconsistent with this proviso, limiting the cost to $1,000,000.

The act making appropriation for the support of the Army, approved March 3, 1869, appropriated $500,000 towards building the bridge.

The agreement between the United States and the railroad company was signed by General J. M. Schofield (then acting Secretary of War), and John F. Tracy, president of the company. It has no date, but it was not many days prior to September 10, for on that day the Chief of Ordnance requested authority to commence the work (the agreement as he states having already been signed) and to authorize the employment of a competent civil engineer to aid in the work.

A marked feature in the agreement signed is the following:

> Provided that the aggregate cost of said bridge shall not exceed $1,276,292.11, the estimate of the same made by the commissioners appointed under the act approved June 27, 1866.

There is no record that the commission made such an estimate, but (as I found on coming in charge of the work in July, 1869) Mr. Johnson, engineer of the railroad company, did make such an estimate, which was for a wagon-road 17 feet wide and a single-track railway. This project was not recommended by the commission nor by the Chief of Ordnance, but a modification of it requiring a wider wagon-way and double-track railway, and this double-track railway and highway could by no possibility have been built for the amount specified in this agreement. It is singular that this discrepancy was not discovered and prevented while the agreement was being negotiated.

It happened fortunately, however, that the amount specified in this agreement is very nearly in accordance with the limiting cost of $1,000,000 for the part over the main river as made in the joint resolution, and *if the repealing proviso of this resolution had been regarded, the previous enactment that the bridge should be built as recommended by the Chief of Ordnance would have been done away with, and no obstacle would have existed in the further prosecution of the work on the best plan with the limit of cost which the joint resolution made.* The commanding officer at Rock Island, General Rodman, having been directed on March 29, 1869, to advertise for proposals for constructing the piers of the bridge, was confronted at once with the question as to what kind of a bridge to build according to the laws, and endeavored to frame his specification so as to meet contingencies that might arise in the settlement of this question. On May 26, 1869, he addressed a communication to the Chief of Ordnance, presenting the whole subject, stating that if the limitation of cost to $1,000,000 in the joint resolution was to include the reimbursements for the cost of half the superstructure, then it was impossible to build the bridge recommended by the commission, nor did he deem it advisable to build such a bridge. He then submitted a plan for a single-track railway with the wagon-way above it, and another for a single-track railway with the wagon-way below it; the latter he stated being not only cheaper, but much more sightly "and incomparably more convenient in itself." He further stated that as the agreements with the railroad company contemplated the wagon-way above, the change would somewhat increase the cost of their approaches, and it would be just to allow them the difference in making the proposed change, and that the company had expressed itself willing to make such agreement. There seems to be no good reason why this should not have been the first plan recommended, and I think it was lawful even at this time.

A contract for Utica hydraulic cement was made on May 31 with James Clark & Son. This contract was for all the cement required at the arsenal as well as the bridge. A contract for Joliet stone for the bridge was made with Sawyer & Talcott, May 15, 1869. A contract for the masonry (a source of great trouble afterwards) was made with Harvey & Livesy June 1, 1869.

General Rodman's plans all contemplated the completion of the piers in the season of 1869. The questions raised by General Rodman as to plan of bridge and cost were referred to Judge-Advocate-General Holt, who gave as an opinion, in a letter dated July 4, 1869, that the plan of this bridge originally recommended by the Chief of Ordnance as named in the act of March 2, 1867, could not be departed from, nor could the provision that the cost, limited in the subsequent joint resolution to $1,000,000, be made to mean that amount exclusive of the amount reimbursed by the railway company. The Attorney-General approved the view of Judge-Advocate-General.

The first-provided bridge would cost double the limit, and under this interpretation the first act was found defeating a subsequent act completely, which had provided "that all former acts inconsistent with it are hereby repealed." The Judge-Advocate-General's opinion makes no allusion to this repealing clause, which effectually did away with former recommendation as to kind of bridge.

A dead-lock was then put upon further proceedings in building the bridge.

The Adjutant-General of the Army, in transmitting to General Rodman the decision of the Attorney-General June 10, 1867, said: "If it is impracticable to construct the prescribed bridge for the sum named, immediate report of it will be made to the Secretary." The substance of this was telegraphed June 10, and on July 11 General Rodman answered by telegraph that it was impracticable. On June 15 General Rodman urged that the clear intention of the law was to build a bridge, and he did not think that any plan could have been intentionally prescribed that would have prevented the main object. He did not, however, refer to the repealing clause in the joint resolution. He was again written to on June 18 by the Chief of Ordnance that the decision could not be changed, but to suspend work until he could reach Rock Island a week thence.

On June 28 the Chief of Ordnance telegraphed from Rock Island:

> Railroad can be built for sum fixed by Congress as to limit, wide enough for double track and strong enough for one train, leaving question of relative position for future determination. The work can be commenced at once. Shall I authorize General Rodman to commence building piers? I recommend it. Railroad company will agree that railroad-track shall run above wagon-road.

On June 29 the Secretary of War telegraphed

> To commence at once. The bridge to be in exact accordance with the recommendations of the commissioners, and not to exceed the limit of cost of $1,000,000.

On June 30 General Rodman informed the Chief of Ordnance that he would proceed at once to construct the piers wide enough for a double track.

WORK TRANSFERRED TO THE ENGINEER DEPARTMENT.

On July 9, 1869, the Secretary of War (Hon. John A. Rawlins) transferred the construction of the bridge from the Ordnance to the Engineer Corps, and on July 10 the Chief of Engineers (General A. A. Humphreys) assigned the duty to me (G. K. Warren, Engineers). Dispatches on this day were sent to me at Saint Paul, Minn., to which place I was returning from several months' duty as commissioner on the Pacific Railroad, which dispatches I received on my arrival there on the evening of the 13th. On the 14th I telegraphed General Rodman as to the necessity of my immediate presence, and gave my efforts to closing up the business that had accumulated at Saint Paul during my long absence, and to giving directions as to the future. On the 17th General Rodman's dispatch said I had better come at once, so I sent Major Stickney down to represent me. On the 20th I submitted a plan for a railwad draw-bridge (made from a section I had sounded in October, 1866, any at which place I measured the velocities), based on the report of Mr. Clarke, engineer of Quincy bridge, to cost $1,000,000, but I had no knowledge then of the difficulties of the case as heretofore presented, much of which was not obtained until as late as December following. I was, however, getting surveying parties ready to make a new survey at Rock Island, as probably would be required. On the 23d of July I received a telegram to proceed at once myself to Rock Island, which I did. The instructions to me were, at the first, to stop all work until I was authorized to proceed, but before authority would be given "the Secretary of War must be fully satisfied that the bridge should conform to all the conditions of proper strength and stability, non-obstructing navigation, and cost." Earnest attention was required, and a full report at the earliest practicable time. On July 21 the contractors were all stopped. At this time the contractors for stone had delivered $15,000 worth. The contractors for building the piers had expended about $4,000 handling and cutting stone, and would lose, they claimed, $2,500 per month by being stopped. General Rodman had, under the plan he adopted, located the abutment on the Davenport side, and the contractors were about to go to work upon it.

I reached Rock Island and received the principal documents from General Rodman on July 26. These were sufficient for continuing the work in the manner laid out by him; but this was all suspended, and I had to make a plan from the beginning. There was an absence of thorough soundings of the river-bed and observed courses of current that called for all the provisions I had made in fitting out a surveying party.* This surveying party, under Mr. J. P. Cotton, civil engineer, at once began to measure the current and obtain the soundings, the latter being a very laborious process in the swift current in the stage the river then was, 7 feet above low water.

Maj. Amos Stickney, Corps of Engineers, with an assistant, was assigned to the duty of obtaining information about and preparing for building the piers. Besides the general supervision of the work, I took upon myself the work of obtaining information on the subject of superstructure, and of finding out exactly the conditions under which the work had been transferred to me. It was soon ascertained that there was no estimate of cost made by the commissioners at Rock Island for a double-track railroad and highway, as recommended by the Chief of Ordnance. This estimate was sought for in every place where it could have been placed, without finding it.

After an examination of all there was known of the subject at Rock Island, I found it would be necessary to visit Washington for consultation and to obtain access to important papers relating to the subject that were still there. Authority was given me to do this, and on the 30th of July I sufficiently understood the subject to prepare a plan for beginning work, which was not materially different from that prepared by General Rodman, except that I did not adopt his location of the piers, and that I required time to make surveys and consider this matter. The delivery and cutting of the stone for the piers, excepting for the starlings, whose form remained a question, was resumed, adopting as the batter for the piers a slope of 1 inch horizontal to 24 inches vertical.

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*Colonel Flagler, in the Annual Report of the Chief of Ordnance for 1877, p. 142, states that "during the year 1869 General Rodman made careful surveys of the bed of the river, measurement of the velocity at different stages of the water," &c. On this point Colonel Flagler is misinformed, for General Rodman made no such surveys. It is due to myself to say this, for the delay I made in submitting a plan was necessary to make such surveys.—G. K. W.

On my return to Rock Island, the survey to get the form of the bed-rock in the river and the courses of the current was pushed with energy and plotted as fast as made. No definite location was advisable until these should be fully ascertained, and thus far they have not been. A survey by a newly-invented sounding arrangement, prepared in the office of the Rapid Improvement, had been made before, but from want of experience of some sort the map made was worthless.

The requirements which the bridge had to fulfill were:

First. Not to cost over $1,000,000 for the part over the main channel.

Second. Not to obstruct navigation.

Third. To accord with the purposes of the United States in the occupation of the island as an arsenal.

Fourth. To meet the wants of the railroad so as to suit its purposes and not necessarily interfere with the streets of Davenport.

Fifth. To have the wagon-road part of the bridge not upon private property.

Sixth. To correspond with the recommendations of the Chief of Ordnance as required in the act of March 2, 1867, to wit, a double-track railway with the wagon-way on top,

Beyond any doubt, the first and last named of these requirements it was impossible to reconcile, and it was thought that if Congress had not already repealed the one last named, it would do so, as all parties interested were in favor of making it a single-track railroad above the wagon-way, because it was better and less expensive. It was decided, therefore, that the piers should be for the least width a double track would require, and not to contract for the superstructure until action by Congress should be taken after a full presentation of the matter at the next session. To meet the requirement for double-track railway, the piers were made longer up and down stream than was necessary for a single-track railway.

The *fifth* of the above-named requirements was very difficult under the plan proposed by General Rodman. In this plan the Davenport abutment was located in the corner of a block owned by the railroad company, the whole bridge passing over the street next the river. Whether there might have been trouble on the part of the city and the railroad company or not in regard to the highway approach, the city government was much dissatisfied with the arrangement. I soon saw, however, that if the city government would consent to raising the grade of Front street about six feet, I could place the abutment at low-water, and descend from the wagon-way placed on the bottom chord immediately into the streets at the intersection of Le Claire, Front, and Second streets, thus giving an easy approach in every direction; while the part of the bridge to carry the railroad might be made of half the strength, and pass over the street to the abutment as located by General Rodman. The city government passed an ordinance establishing the grade as I requested, and so this difficulty was removed.

The *fourth* requirement gave me comparatively little trouble, as it had been well met in the location made by General Rodman.

When the current observations and soundings had been only made in part, I thought I would have to move the Davenport abutment upstream or the Rock Island one down; but fortunately this was found finally to be unnecessary, and so General Rodman's position for the axis of the bridge was preserved. This line was so chosen as to cross the main river and island and a considerable portion of the slough on a straight line. The Rock Island City end, coming at the end of the embankment of the old slough bridge, enabled the new bridge to be easily built without disturbing the running of the trains, while the Davenport end landed on the railroad company's property, so that the right of way was secured to them, and this they had obtained with special view to passing over the streets of Davenport to their main track.

The *third* requirement, "the uses of the island for the purposes of the government," was also secured in this location, as fixed by General Rodman.

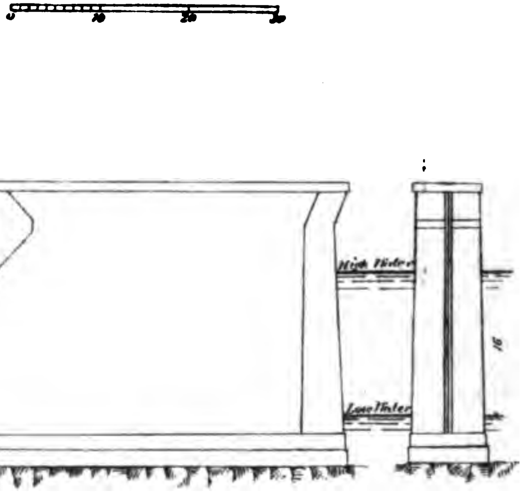
The *second* requirement seemed to me the most important of all.

The current-measurements soon showed that the axis of the bridge, as thus determined, was at right angles with the course of the current at the two stages measured, and the form of the bed brought out by our soundings, of which about 8,000 were made and located by triangulation, gave reason to believe the currents would not materially change direction at any stage. As a consequence of this, the piers would be parallel with the current, as required by law, if placed at right angles with the axis of the bridge, and we should thus gain the full practical width for the passage of water through sections whose lengths were equal to the clear spans. My own observation and study had satisfied me that draw-bridges should be so located as to have one draw-opening next the shore. On being placed in charge of the work, the steamboat-men were consulted, and the presidents of the two packet companies wrote me letters urging that the pivot-pier should be so placed as to be next the shore. The depth of water on the Davenport side was too little to allow of the draw being placed there without a much more considerable rock excavation than was needed on the Rock Island side. In addition, the current was more gentle on the Rock Island side, and it was quite near the middle of the river, when we consider the landing at Rock Island City on the main-land, as well as Davenport. Another important economical feature in the construction was, that the large pivot-pier on the Rock Island side could be built in comparatively shoal water with deep water alongside of it. I therefore decided upon a location of the draw next the island. It may be noted here, that one apparent provision of the law was neglected, which requires the spans next the draw to be 250 feet; but it is evident that the law intended the draw to be at the best place for it, since it accommodates all the steamboats, and the other only rafts, and it is not to be supposed that the draw-openings, which were so objectionable in the old bridge on account of swift current, should be again built in swift current to meet this secondary provision, if it could be avoided. The use of the draws of several bridges now built on the Mississippi has been impaired by the designers not taking the same views of the case which I did. This location of the draw, however, was objected to by the commanding officer of the arsenal, in a communication dated November 3, 1869 (see Annual Report Chief of Ordnance, 1877), as interfering with the steamboat landing it might be necessary to have on the island just above it, &c. The whole question was argued before the Secretary of War by me April 21, 1870 (see Annual Report of Chief of Engineers for 1870, pp. 229–236), in the interest of navigation. The Chief of Ordnance replied that if those interests required the draw-bridge there, he could conduct the affairs of the arsenal so as not to interfere with it, and so it was decided to let my design remain unchanged. I will say here that in all my relations with the ordnance officers I was treated in the most frank manner, and aided in every way I could expect, although persons friendly to them expressed themselves in the newspapers as hurt at the summary manner in which the building of the bridge had been transferred to another department.

Rock Island, Ill.
New Bridge.

ELEVATIONS OF PIER 3.

Scale of Feet



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Arrangement of spans.—The limitations of the law as to cost required me to use the most economical plan I could adopt, and not select unusual spans for the main part of the bridge. I therefore made the span on the river side of the draw 260 feet from centers, and divided the remainder into four equal spans of 230 feet each, reaching to the Davenport abutment, situated at low-water line. At a subsequent period, for the use of rafts, I altered the plan so that the one next the Davenport abutment should have a span of 260 feet (in the clear 250 feet), and proportionately reduced the three adjoining ones. It is questionable whether this last change was best, as there has been a disposition in Davenport to obstruct the use of this opening. But for the limit of cost, I would have at first planned for four spans of 295 feet, instead of five spans, between the right res t-pier and the Davenport abutment.

Form of piers (see 'Diagram B).—The form of the upstream starling from the first attracted our attention on account of the great power of the floating ice at this locality. The ordinary rise from low to high water is about 16 feet; but sometimes, on the breaking up of the ice below the bridge, a gorge is formed which raises the water to 21 feet above low-water. At such time, it may happen that the ice above the bridge is loosened from the banks in large cakes or fields while it is still firm; it then moves down with great force, when the ice-gorge below gives way. I therefore thought it best to carry the inclined upper starling at a slope of 1 to 1, from low-water to 21 feet above, which gives the pier a very considerable extension in the direction of the stream. The form of the horizontal section of the starling adopted is that given by two circles whose radius is equal to the width of the pier at the section. These circles are described with the opposite side as centers, so as to be tangent to the sides of section, and intersect at the nose with an angle there of 120°. With the common form of triangle for horizontal section, this angle is only 90°, and the angle with the sides is 45°, instead of tangent as in this case. The nose of the pier is thus formed by parts of two oblique cones with circular bases. The lower edges of the stones on each course are thin, and unavoidably so if the nose of the pier is allowed a slope of 1 to 1. Perhaps 3 on 2 would have answered, and it would have been less expensive. It was at first thought to cut the stones with steps in the upper edge, but as the only injurious effect of time and use would be to reduce them to steps, they were cut with smooth surface. The cut-water of the starling was protected by iron plating. The downstream starling of the piers is a half cone with circular base. The piers were designed to be 36 feet long and 7 feet wide under the coping, exclusive of the starlings up and down stream; but before they were built Congress passed a law allowing the bridge to be for a single-track railway. The length of the piers was shortened 4 feet, and they were built 32 instead of 36 feet long.

The main draw-pier is built for its special objects, and is of the following description: The center or pivot tier is circular, 36½ feet in diameter under the coping, with a batter of 1 to 24. The upper and lower rests are of masonry; the upper one with a triangular starling with the same slope as the piers, and the lower one a semicircle. The space between the pivot and these rests is a timber crib with apartments filled with riprap. In designing these piers it was sought to take the least possible width from the stream, because all diminution of the natural section resulted in an increase of velocity, the rock bed not admitting of any enlargement of section by scouring between the piers. The area of the natural high-water section (not that of the ice-gorge high-water) was 35,800 square feet. The abutments diminish the width by about 90 feet and the sectional area by 175 square feet, but this is nearly all taken out of slack-water along the shore and does not materially affect the mean velocity. The piers occupy about 1,928 square feet, which is about .056 of the available section for flowage, and they consequently increase the mean velocity above that in the natural section by about .059 of the mean of the natural section. The draw-openings, however, are in a part of the river where the velocity is moderate even at high stages.

During the progress of forming the present plan of bridge I engaged Mr. George C. Herthel, of Saint Louis, to aid me in calculations concerning superstructure, and Mr. Jacob Blickensderfer in regard to questions of strength of piers, abutments, &c. The position of the piers had been so far determined by the 23d of August that the contractors were informed that they could at once proceed with the Davenport abutment and contiguous pier. The water was then 6 feet above low water. They, however, did nothing at these points, and September 13 they stated they were ready to go to work as soon as the government made the coffer-dams, pumped them out, &c. On the 14th they were informed that this work was included in their contract. On the 15th they filed a protest under which they were willing to work, claiming special compensation for the coffer-dams, &c. The same day, to prevent any further delay, I consented to their going to work, they neither waiving any claim they had rightfully nor I admitting anything they claimed. This action on my part was duly reported and approved. They began work on the coffer-dams September 16. This first trial showed their appliances to be very inefficient. The river had again begun to rise.

By the 20th of September I had everything arranged for the continuous work on the piers, and made my annual report, which recites some of what I have given here and enlarges upon matters not here presented. (See Annual Report of the Chief of Engineers for 1869, pp. 194-198.)

On September 22 I assigned Bvt. Maj. W. H. H. Benyaurd, Corps of Engineers, who had been ordered to report to me for duty, to the task of looking up the whole subject of superstructure by visiting the different bridge-builders and their works, and to collect data needed for a special report to secure the change in the law deemed necessary under present interpretation of existing ones. I then proceeded to give personal directions in regard to some of my other works, and to make a final examination of the Wisconsin River in company with Mr. Jacob Blickensderfer, whose services I had obtained for that purpose. As soon as I had finished the provisional location of a canal along the banks I returned to Saint Paul and worked up the estimates of quantities and cost. When this was finished Major Benyaurd had procured the information he was sent for, and I took it up and wrote another report about the Rock Island bridge, dated December 3, 1869. This is printed in the Annual Report of Chief of Engineers for 1870, pp. 240–246. Here the argument is fully given to show that the repealing clause of the joint resolution of March 2, 1867, did away with the recommendation of the Chief of Ordnance provided in the act of March 2, 1866, and that the Secretary of War could build a single-track railway above the wagon-way without any further legislation, if the cost was kept within the limit provided in the joint resolution. All the engineering data were, however, given in this report. The matter was referred to Congress, and it passed a joint resolution authorizing the bridge as a single-track railway, with wagon-way underneath, as recommended. All obstacles to an easy and rapid construction of the bridge, if low-water favored during the ensuing year, were now removed, except for the inefficient contractors and the unsatisfactory contract for building the masonry.

The original proposal of the men was sufficiently informal to have justified its rejection; but it was accepted, and the contract drawn by General Rodman, with the intention of making it binding and explicit. The contractors, however, claimed a different understanding of its terms than was allowed by the officer making it, as already stated, and probably regarded their inefficient prosecution of the work as unavoidable in consequence. A bad feature of the contract was that they were to be paid for finished work measured in the piers, and this precluded my paying them for cutting and handling the stone at a pro-rata valuation, which it would have been safe for the United States to do. I could not obtain authority to depart from the strict letter of the contract, and so they were embarrassed for want of payment for work done. The season of 1869 was the most remarkable for continuous high water of any on record, and very unfavorable to this work. Work was resumed in the spring of 1870 on the Rock Island abutment, but high water prevented work on any of the piers. On May 16 I issued the specifications for superstructure which had been prepared, and advertised for proposals for building it. I turned over the work to Col. J. N. Macomb on May 30, 1870. Subsequently I reported on the proposals and concurred in the award that was given of the work to the Baltimore Bridge Company. Colonel Macomb retained Major Stickney in charge of the substructure and Major Benyaurd in charge of the superstructure. The contractors made so little progress in the construction of the masonry that the work was taken from them and completed by hired labor under the officers in charge.

I believe there was no material modification of the plan made by me. The passage-way between the pivot-pier and the island was deepened, but the intention I had to smooth the Rock Island shore and protect boats by means of fenders was not carried out. The part of the bridge over the slough and the causeways across the island, and the approaches in Davenport, were built by the railroad company. The whole was finished and opened to the public October, 1872.

GENERAL DESCRIPTION OF THE LOCALITY AND BRIDGE.

(See Diagram 19.)

This bridge is situated at the foot of Rock Island Rapids (the greater portion of which island is above overflow), where the bed of the river is of limestone, the same as above to Le Claire. The width of the river between the Iowa shore and the island of Rock Island is 1,650 feet at the site of the bridge. Immediately below the foot of the island the width of the river increases to 3,000 feet.

The channel on the Illinois side of Rock Island, which formerly received a portion of the water of the river, has been for many years closed by a dam, recently rebuilt by the United States Government, so that no water other than what is used to drive the mills at Moline passes through it. The slope of the river above the bridge is 1.7 feet per mile, with a maximum velocity of 4½ miles per hour at the new bridge, where the water is 12 feet above low water.

The rocky shores on the rapids for 18 miles above this place, against which a raft cannot land, together with the swift current, makes the running of rafts in this part of the river very difficult. There are but two or three places at which they can tie up, and if these are missed they must run through the bridge in any wind that may rise while they are passing over this distance.

DESCRIPTION OF THE BRIDGE.

(See Diagram 20.)

The bridge, commencing on the Davenport side, is approached by the railroad on a curve of about 1,200 feet radius from the main track on Fifth street to the junction of Fourth and Rock Island streets, which is crossed diagonally on a bridge of one span, giving about 12 feet headway to the streets. The approach then continues on the diagonal to the intersection of Third and Iowa streets, which is crossed by a single span of about 120 feet; then it is on a curve of about 1,700 feet radius to the junction of Second and Front streets, which is crossed by a span of 196 feet to the main bridge. There is 12 feet headway above the wagon-road floor. The main bridge has one span of 260 feet, then three of 220 feet, then one of 260.5 feet, and then the draw, 370 feet from end to end, with two clear openings of 160 feet each. A span of 80 feet then carries the railroad-track to the embankment on the island. This embankment extends across the island on a grade of 30 feet to the mile. Then comes a span of 80 feet over the island wagon-way; then the embankment continues 700 feet farther to the abutment of the slough bridge. This latter has four spans of 150 feet each, and then there is an embankment on a 4° curve to the main track.

Masonry.—The masonry of the bridge has already been described. The piers in the slough are of masonry, resting on piles. This channel has but little current, it being only the tail-race of the water-power at the head of the island. No special care was observed as to direction in crossing it, or in the obstruction of the water-way.

Superstructure.—The bridge is of wrought iron throughout. The upper chords are of rolled channel-bars, and the lower, open links in the fixed spans. In the draw-span both upper and lower chords are of channel-bars. The draw is opened and closed by an engine placed on the outside of the truss, on a level with the railroad-floor. Great care is necessary in handling this heavy draw in time of high wind. The posts are Phœnix beams. The railroad-floor beams are attached to the posts so as to form a system of lateral bracing. The bridge over the main river was built by the Baltimore Bridge Company, Mr. C. Shaler Smith, chief engineer. On account of the limitation of cost provided in the law, the specifications called for wooden floors for both rail and highway. If the means admitted, this should have been changed to iron. When it becomes necessary to renew them, iron should be substituted for the wood.

INFLUENCES ON NAVIGATION.

This bridge has met the wants of navigation as fully as a low drawbridge is capable of doing. The locality is particularly favorable to this kind of bridge, as there is sufficient depth of water for boats and rafts from shore to shore, and the rock bed renders a change in this impossible.

ALTERATIONS TO LESSEN OBSTRUCTIONS TO NAVIGATION.

Sheer-booms.—The Board of Engineers on sheer-booms recommended that a sheer-boom 1,200 feet long be placed with its lower end, when in position, resting against the Davenport rest-pier.

Finishing the work in left draw-opening.—This Board also recommended the timbering and planking of the rocky shore of the island for 500 feet above the bridge. This was part of the original plan, and should have been carried out if there had been funds to do it.

HIGH BRIDGE.

It is probable that this is one of the last places on the Mississippi River that will require the low draw-bridge to be replaced by a high one. When done, it should be placed at least 77 feet above low water, to enable boats to pass under it at all times when they can pass the bridge at Saint Louis. (See Discussion, Chapter III.)

BURLINGTON RAILWAY DRAW-BRIDGE.

(Opened for railway travel in 1868.)

Authority.—This bridge was built by the Burlington Bridge Company in 1867 and 1868, under act of Congress approved July 25, 1866.

DESCRIPTION OF THE RIVER AND VALLEY AT THE LOCALITY.

(See Diagram 21.)

This bridge crosses the Mississippi River about 4,000 below the steamboat-landing at Burlington, Iowa. The river at this point is about 2,100 feet wide between the low-water banks, with a large extent of bottom-land overflowed 5 to 10 feet at highest water, extending to the Illinois bluffs, making the width of the high water river about 5 miles.

The channel of the river for 5,000 feet above the bridge and 3,000 feet below runs along the west bank in a direction for the most part parallel with the shore, which is rocky. The bluffs rise abruptly from the shore except at the site of the town, which is in an opening in the bluffs through which Hawkeye Creek flows. The river for two miles above and one below the bridge is confined to one channel, in which there is always a good navigable depth. The slope of the river at low-water is 0.27 foot per mile. The bed is generally sand. The depth to bed-rock is not known, except for that part from the west or right bank to the pivot-pier, where it is about 30 feet below low water. The rise from low to high water is 20 feet.

SURVEYS.

A survey was made by us here in 1866 extending about 2 miles above and 2 miles below the bridge-site. The location of the bridge had not at that time been made, or, if made, was not generally known, so that no special examinations of the bridge-site were made. The survey consisted of a meander of both shores of the river; location of sand-bars; levels to ascertain the slope of the water's surface; soundings over the section surveyed; and measurements for volume of discharge. A survey including current-observations was made in 1868 after the bridge was built. The water then was about 4½ feet above extreme low-water. The maximum velocity at the bridge was about 2¾ miles per hour; that in the channel 2,000 feet above was about 2¼ miles per hour. Current-observations were again made in October, 1869, with the water 11.6 feet above low-water. The maximum velocity was about 4¼ miles per hour.

DESCRIPTION OF THE BRIDGE.

(See Diagram 22.)

The bridge is approached from the west on an embankment with a curve of about 720 feet radius. The first span is 175 feet long from center of abutment to center of first pier—part of the span being over the land. The second span is 200 feet long. The trusses of these two spans are wider than those of the rest of the bridge, to allow the curve of the approach to be extended on the bridge. The next span is a pivot-draw 360 feet long over all, with two clear openings of 160 feet each; then there are 6 spans of 250 feet each from centers, and then trestling for a few hundred feet, which last is considered temporary and is to be replaced by an embankment. The whole length of the bridge is 2,235 feet.

Masonry and foundation.—The masonry is built of stone from Athens, Ill., and Le Claire, Iowa. All of the piers rest upon piles cut off about 5 feet below low-water. The piers, in this report, are numbered from the right bank. The piles for foundation of piers Nos. 1 and 2 were driven to bed-rock, which was struck about 30 feet below low-water. Part of the piles in the foundation of pier 3 (pivot) were driven to bed-rock. The piles in the foundation of the other piers were driven from 20 to 25 feet into the bed of the river. The distance to the rock is not known. Under pier No. 1 there were 140 piles; under pier No. 2, 170 piles; under pier No. 3 (pivot), 333 piles; under pier No. 4, 170, and under each of the others about 140. The masonry was built upon a grillage of timber, which rests upon the heads of the piles.

The dimensions of pier 5 (see Diagram C′) are, length 24 feet, width 8½ feet. The batter is one-half inch to the foot. At a point 9½ feet below the level of the bridge-seat, 2 feet above highest water, the starling commences. The horizontal section is in the form of an equilateral triangle, and the cut-water has a slope of 8 inches to a foot vertical. The lower ends of the piers are frustums of a right semi-cone with a circular base. Where the piers rest on the grillage the length is about 57 feet, and width 16½ feet; the lowest 5 feet being of three courses, each offsetting 6 inches all around. All the others are similar to pier No. 5 except the rest-piers Nos. 2 and 4, which are one foot wider. All of the piers except the draw-pier have detached ice-breakers; these were not built when our examinations were made in 1868, and when the bridge was surveyed in 1869 the high water prevented our examining them. The draw-rests are pile-cribs built to above high water, with their sides planked; at the upper and lower ends there are timber cribs filled with riprap.

The *superstructure* of this bridge is of iron. The fixed spans are quadrangular girders with cast-iron upper chords, Phœnix-rolled posts, and bottom chords of open links. The draw-span has both chords of rolled channel-beams riveted together. The whole superstructure was built by the Detroit Bridge and Iron Works, at the same time and under the same requirements as the bridge at Quincy. No account of the building of this bridge has been published that we know of.

INFLUENCE UPON NAVIGATION.

At the time of the examinations in October, 1868, the current measurements show that the general direction of the current made an angle of about 5° with the axis of the piers. The maximum velocity was through the west draw-opening.

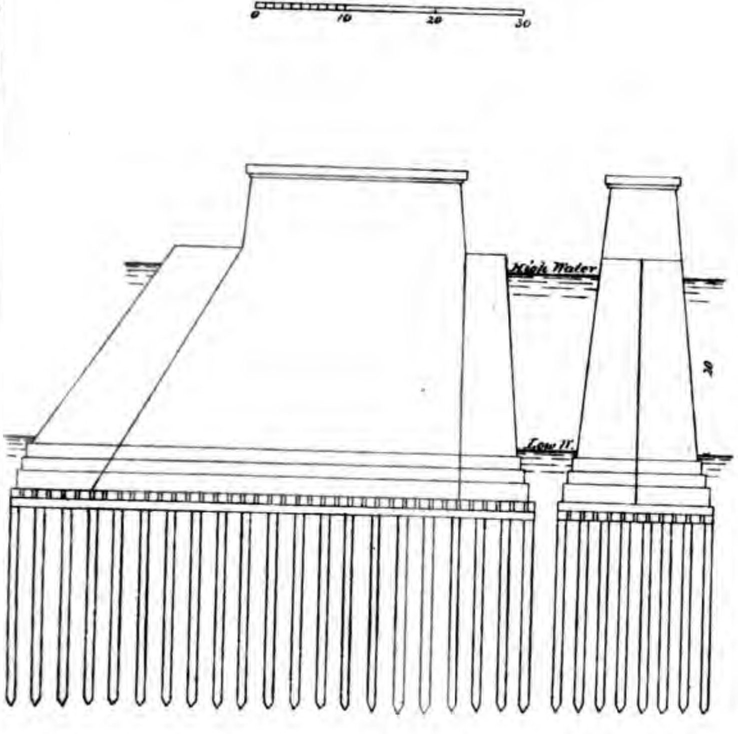
A hard gravelly point makes out from the Iowa shore, about 500 feet above the bridge, which at the time of this examination deflected the current from the shore. This gravel-bar is probably composed of the coarser material brought into the river by Hawkeye Creek, and has become packed together so hard that it resists the action of the water even at flood velocity. This point acts differently at different stages of

Warren's Report Bridging Mississippi River. *Diagram C'.*

Burlington, Iowa.

ELEVATIONS OF PIER 5.

Scale of Feet



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water; with the water high enough to run over it, it deflects the current but little; but when the water falls below, the current is deflected toward the right draw-opening, so as to cause a cross-current through this opening. The filling out of the shore-line above this point would probably remedy this somewhat; this filling had been commenced by the railroad company to make ground for depot-buildings.

We again examined this bridge in October, 1869, when the water was 11.6 feet above extreme low-water. The direction of the current at that time was nearly parallel with the axes of the piers, making in the approach to the draw-openings an angle of but 4°. The maximum velocity was through the right opening of the draw, in the same locality as the maximum velocity of low-water.

Passage of steamboats.—The location of a bridge below a landing is objectionable. Steamboats descending the river make the landing above the bridge with bow upstream; all boats have to do so on this river on account of the current. On leaving the levee they must turn around and get into position before they can pass through the draw; while trying to do this they are often carried down by the current so near the bridge as to compel them to back into position, thereby losing much time. Again, a boat breaking from her moorings at the landing is almost sure to be carried on to the bridge, endangering both boat and bridge. The bad effect of this location would have been much lessened if the Iowa bank had been made straight and filled out to the line of 5 feet depth at low-water, as far up as Berry's Mill, and the draw placed next to the shore. This would have given a much better opportunity to pass in bad weather and dark nights. The bridge company disregarded the requirements of the law to put a 250-foot span adjoining the draw, so that the provisions of the law cannot be given as a reason for not putting the draw next the shore. This arrangement would have made the passage no worse for rafts than it now is. There is a bar above the bridge, on the left side of the channel, similar to that at Quincy, but not seriously objectionable in its influence, as it leaves a channel-way 800 to 900 feet wide.

Passage of rafts.—There are six spans east of the draw, of 250 feet each from center to center (seldom used by rafts because of the bar and set of current above them), but the span next west of the draw, in violation of the law, is but 200 feet. The channel for some distance above the bridge being along the Iowa bank, rafts are generally brought down that shore, since, by so doing, they are sheltered by the bluffs from winds. Upon approaching the bridge, if the raft is too wide to pass through the 200-foot span it must be moved sidewise about 500 feet, across the swiftest part of the current, so as to pass through the first 250-foot span on the left side of the draw-openings. This is an operation so difficult as to be seldom undertaken by a raft without employing steam-power.

The position of the gravel point before alluded to renders the use of the 200-foot span quite difficult at a medium or lower stage of water. The usual manner of passing rafts when managed by means of a steamboat is to divide them into two parts above the bridge, and take one through the 200-foot span and the other through the draw-opening. In passing the 200-foot span they are drawn by the current toward the Iowa pier in high-water and toward the other pier in low-water.

ALTERATION TO LESSEN OBSTRUCTIONS TO NAVIGATION.

Sheer-booms.—The Board of Engineers in their report on sheer-booms recommended that a boom should be extended 900 feet upstream with its lower end resting against or attached to the right rest-pier. The raft interest desired that another boom 1,000 feet long should be placed on the upper end of the draw-rest extending upstream and flaring toward the Illinois shore, showing that they do not care to use the present 250-foot span. But this boom would interfere with the passage of the bridge by steamboats, and could not be allowed. This want of the raft interest shows that the long spans to the left of the draw are of little or no use for passing rafts.

Change of span.—A change which the raft interest would have a right to demand is a reconstruction of the span on the Iowa side of the draw so as to make it 250 feet. If this should be done the shore-end should rest on an abutment and the shore-line brought out to a line joining the abutment and Berry's boom-pier, about 700 feet above. The opening thus provided and the point above should be dredged out 3 to 4 feet depth at low water. With this change it is thought that no sheer-booms will be needed at this bridge.

HIGH BRIDGE.

The building of a high bridge at this place would not involve great expense for approaches, as the Iowa approach offers a choice of high or low ground, while that on the Illinois side is low and not valuable. A high bridge at this place should be 77 feet above low water, or 57 feet above high-water.

KEOKUK RAILWAY AND HIGHWAY DRAW-BRIDGE.

(Opened for travel in 1870.)

Authority.—This bridge was built in 1869 and 1870 by the Keokuk and Hamilton Bridge Company, under act of Congress approved July 25, 1866.

DESCRIPTION OF RIVER AND VALLEY AT THE LOCALITY.

(See Diagram 23.)

The river in its natural condition at this place is about 2,600 feet in width at ordinary low water, and about 5,500 feet in width at flood stages. The bed of the river is limestone, of the same character as that of the whole of Des Moines Rapids, which extend from this place to Montrose, about 11 miles above. The slope of the river for this distance averages about 2.2 feet per mile, but in places in the lower part of the distance it is as much as 3 feet per mile. Immediately below the bridge the low water-width increases, the slope becomes small, and the rocky bed is replaced by sand. The rise from low to high water is about 22 feet.

SURVEYS.

A survey of about 1½ miles of river was made at this place in October, 1866, after the passage of the act authorizing this bridge, but, as the location had not then been made, the survey was made general over a section supposed to include its probable site. The water at the time of making the survey was about 2.5 feet above low water. After the location of the bridge had been determined upon and work commenced another survey was made. This was in October, 1869, when the water was 12.8 feet above low water. Again, in October, 1876, after the bridge was opened and the canal nearly completed, another examination was made, with the water 5.8 feet above low-water. The results of the two last examinations are taken up in treating of the "Influences upon navigation" of the bridge.

DESCRIPTION OF BRIDGE.

(See Diagram 24.)

Arrangement of spans.—The river is spanned by twelve spans of the following lengths, commencing at the Keokuk side and measuring along the axis of the bridge and from center to center of piers: First, a pivot draw-span 380 feet long from end to end; this length was intended to give openings of 160 feet at right angles to the axes of the piers. Then come spans of 258 feet, 256.3 feet, 162.6 feet, 162.5 feet, 163 feet, 151.5 feet, 164.9 feet, 165.1 feet, 164.3 feet, and 165 feet, respectively, making the total length of bridge about 2,190 feet. On the Illinois side there is a high embankment for 1,930 feet; about 500 feet of this is in the low-water channel-way, but the old transfer embankment above it still stands and occupies a greater space of the water-way; there is next a single span of 95 feet over a slough, and then the embankment is continuous to the high ground, a distance of about 1,200 feet, making a total length of bridge and embanked approach on the Illinois side of 5,475 feet. The approach on the Keokuk side is over a structure of masonry on a curve of about 850 feet radius, the abutment being about 160 feet from the shore-line. The Illinois approach and the bridge are on a straight line. The Keokuk end of the bridge is about 900 feet below the lower end of the Des Moines Rapids Canal, now about completed.

Substructure.—The piers are constructed of limestone, the greater part of which came from quarries in the immediate vicinity. They rest (or part of them do) upon a timber grillage, and this upon the rock of which the bed of the river is composed. The pivot is circular, provided with slots in which the ends of the floats between the pier and rests slide, as water rises and falls. The rests are built of timber, filled with riprap. Between the pivot-pier and the rests is a crib-work built up to a height a little above low-water. Above this is the float.

In October, 1876, these floats were much out of repair, and were prevented from resting on the cribs by drift-wood lodged between them and the cribs.

The piers and draw-rests are built with their axes at an angle of 72° 45′ with the axis of the bridge, so that the openings between them are not that represented by the length of the spans, but by this length into the sine of the angle which the axes of the piers make with the axis of the bridge, so that the draw-spans of 190 feet from center of pivot to center of rest-pier are but 181.4 feet when measured at right angles with the axes of the piers.

Superstructure.—The bridge was built by the Keystone Bridge Company of Pittsburgh, Pa., in 1870. It is of wrought iron throughout, except the head and foot of posts and angle-plates of upper chords, which are of cast iron. The trusses are 21 feet high except the draw-span, which is about 35 feet at the center and 21 feet at the ends. The trusses are 23 feet wide from out to out, with sidewalks 5½ feet wide on each side. The floor-beams are of two channel-beams, 10 inches deep; these are trussed, and extend outside of the main trusses to support the sidewalks.

The bridge was built for rail and highway travel on the same floor.

The whole bridge, including sidewalks, is floored over at the same level, the top of the track being about 1 inch above this floor.

The draw is turned by a small steam-engine on the turn-table, the greater part of the machinery being below the floor of the bridge. Provision is also made for turning it by hand.

The bed of the river at this bridge being of rock, makes the question of contracting the water-way an important one, as every obstruction placed in it must increase the velocity.

In October, 1869, when the water was 12.8 feet above low water, we measured the velocity at this place. The canal-lock was then in process of construction and occupied about 400 feet in width of the low-water section; the transfer approach on the Illinois shore extended into the low-water river about 700 feet, at a point about 100 feet above, leaving a low-water width of but 1,700 feet, and at the stage 12.8 feet above low-water a width of 1,900 feet.

The piers of the bridge were not built. The maximum velocity was about 4½ miles per hour.

In October, 1876, we again measured the velocity here with water 5.8 feet above low water, with the same width of water-way except the additional obstruction of the piers of the bridge. The maximum velocity was then about 3 miles per hour. This was through one of the long spans to the left of the draw-span.

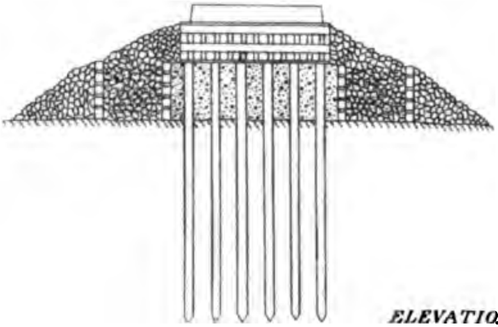
INFLUENCES UPON NAVIGATION.

At the time of our examinations, in 1869, the site of the bridge had been fixed upon and the approaches were nearly built, but no piers had been built in the river. As no obstructions had been placed in the river the direction of the current was the same as when the location of the bridge was determined upon. The current at that time approached the line of the axis of the bridge at an angle of 65°, or at an angle of 7¾° with the axes of the piers as afterward built. The water at that time was 12.8 feet above low-water.

When our examinations were made, in October, 1876, the greater part of the right hand draw-space was obstructed by a coffer-dam put in by the government in order to deepen the channel from the foot of the canal-lock down through the right draw-opening. This dam extended from the lower end of the canal-bank down to the upper draw-rest. In this distance about 250 feet had been partially removed, but, as it was nearly parallel with the general direction of the current, it was impossible for a steamboat to use it, and, as the canal was not in use, the right-hand draw-opening was entirely unavailable for the passage of rafts or steamboats. The existence of this coffer-dam prevented the water from being drawn into this opening and was therefore favorable to a direct flow of the current through the left draw-opening and adjoining long spans. Had the space between the canal-wall and head of upper draw-rest been open, there must have been a strong current into the tail-bay of the canal. The existence of such a current would make the passage of the left draw-opening difficult, and at times of high-water very dangerous. With this opening so nearly closed the general direction of the current made an angle of 6° with the axes of the piers, and 66¾° with the axis of the bridge. The clear opening in the left draw-space, measured at right angles to the general direction of the current, was about 125 feet. This distance was measured at right angles between two parallel lines drawn in the general direction of the current—one from the lower end of the lower draw-rest, the other tangent to the west face of the left rest-pier.

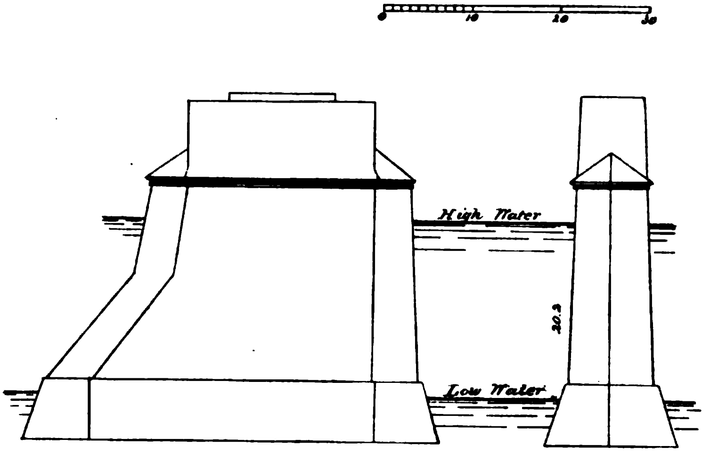
Quincy, Ill.

FOUNDATION



ELEVATIONS OF PIER 4.

Scale of Feet



AM. PHOTO-LITHO. CO. N.Y. (OSBORNE'S PROCESS.)

the heads of the piles, which were sawed off at 5½ feet below low-water, and the space between them filled with riprap and concrete. A grillage consisting of three courses of timber was floated into place and suspended by ten screws 2¾ inches in diameter, having four threads to the inch. The masonry was built upon this grillage and the whole lowered into position by these screws; some of the grillages were thus lowered as much as 15 feet.

From pier 6 to the east shore the cribs had to be sunk before the piles were driven, on account of the sand. Before sinking these cribs the sand had to be dredged out. After the cribs were sunk the piles were driven from leaders resting on the cribs and sawed off, concrete being placed about and between their heads. The foundation of the abutments of both main and slough bridges was formed by inclosing the space with sheet-piling, and then excavating to 2 feet below low-water. A foundation of concrete 2 feet thick was then put in and the masonry laid upon it. All of the piers were built with a rough ashlar stone-face backed by concrete.

Detached ice-breakers were built to piers 2, 4, 5, 6, and 7. These ice-breakers are constructed of 22 piles driven in the proper form, the outer row sawed off 1 foot below low water. A crib 20 feet by 45 feet is sunk around these and filled with riprap to within 2 feet of low water, and riprap is placed outside to protect it. The ice-breaker resting upon these piles is built of oak timber 9 inches by 9 inches, sheathed with ¼-inch boiler-plate and finished with 4-inch angle-bar running the whole length of the nose. Each ice-breaker is filled with concrete from 2 feet below to 8 feet above low-water. The upper guard-rest is built to serve as an ice-breaker. Between the guard-rests and pivot-pier are cribs resting upon piles. These piles are sawed off about 4 feet above the sand-pockets or compartments, which were filled with riprap. The cribs are built up to 6 feet above low-water. Upon each of these cribs rests a float of white-pine timber. The sides of these floats are of 2 courses of 12 inches by 12 inches, sheathed with 4-inch plank and united by diagonal ties and bracing 12 feet apart. The ends of the floats are provided with cast-iron rollers, which run in slots in the masonry of pivot-pier and in the upper and lower guard-rests to allow them to rise and fall with the water.

Superstructure.—The superstructure was built by the Detroit Bridge and Iron Works. The fixed spans of the main bridge are quadrangular girders with cast-iron upper chords, Phœnix-rolled posts, and bottom chords of open links. In the draw over the main river both chords are rolled channel-beams riveted together. The width between all trusses over the main river is 14 feet; their heights vary. The 250-feet span is 26 feet high, the draw-span 26 feet high at ends and 34 feet at the center; the 200-feet spans 24 feet; eleven spans of 157 feet are 22 feet high, and the 200-feet span next to east shore is 22 feet high.

The bridge over the bay is a Bollman truss with cast upper chords and posts. The draw is the same with riveted upper chords, supported by hog-chains over a central tower. The spans in the bridge are all 10 feet high, with track on top of upper chord. These trusses are 10 feet wide. The draw over the main river is turned by a small steam-engine placed on the turn-table outside of the truss. It is also provided with means of turning by hand. The draw in the bridge over the bay is turned by hand.

INFLUENCE UPON NAVIGATION.

At the time of our examinations in 1868 the water was about 5 feet above low-water, and 15 feet below extreme high water. The west draw-opening was temporarily unavailable by reason of the sinking of the steamer G. D. Palmer and two barges a short time before. These ran upon the upper draw-rest and sank in the west opening. A sand-bar forms above the bridge, and frequently when low water occurs it occupies the greater part of the water-way.

Mr. T. C. Clarke the engineer of the bridge, in his published account, says it is constantly encroaching on the channel at low water, and as constantly being swept away again at high water. The only danger is that a portion of the discharge at low-water may find its way down along the east shore, diminish the volume of flowage in the main channel, and allow the bar to encroach too far. This actually occurred during the summer of 1868, but was effectually stopped by building a low wing-dam on the Illinois shore, which confined the current to the main channel.

Our current-observations show the current to approach the bridge at an angle in the first 1,000 feet above the bridge of 6°. This direction and the position of the bar make the east draw-span difficult to reach from above by reason of this bar approaching within 800 feet of the upper end of the draw-rest measured in prolongation of its axis.

The width of the channel between the bar and the west bank was about 400 feet. The middle of east-draw opening is about 500 feet from the west bank, so that descending boats were obliged to hug the bar very closely to go through it. Boats heavily loaded, or with tows, were sometimes compelled to stop a short distance above the bridge and back until they got into position for running through this opening.

This difficulty in using the left draw-opening would not have been so great if the pivot had been placed with the right draw-opening next the Missouri shore. There would besides have been the further advantage to navigation in this position that, in time of high winds, dark nights, or thick weather, vessels could have hugged the shore and been thereby safely guided into the draw-space, or by passing lines to the shore might drop down or warp up.

The constructor of the bridge foresaw this, but was apparently controlled in the course he took by the feature of the law which prescribed that the "next adjoining spans shall not be less than 250 feet." This provision is really a defect in the law. In many cases it is impracticable to carry it out without great injury to navigation. In some places besides this, to be mentioned hereafter, it has been but partially met, and in several others neglected, as at the new Rock Island, Winona, and La Crosse bridges, where the draw is placed next the shore. In the course pursued at Quincy bridge, the constructor either neglected another provision in the law or demonstrated another defect in it. These spans of 250 feet were provided for the use of rafts, which at least implied that they should be spans over the water-way at times when rafts were running. But as a part of the span is over the land (the support on which it rests being 30 feet inside of the ordinary low-water line), it allows 30 feet less for the rafts than there should have been. If this is allowable, there seems no reason why the whole span could not, by the same interpretation, have been placed out on the low-water bank, thus placing the draw next the shore. To have placed the Quincy draw next the shore would have made both draw-openings at all times available, but the 250-feet span on the side away from the shore would have been difficult for rafts, although not so much so as it now is. On the other hand, to have made the full 250-feet span between the draw and the Missouri shore available would have increased the unfavorable influence of the bar upon the use of the draw-opening farthest from the shore, while making more favorable the passage of rafts. On the whole, the present conditions are somewhat of a compromise upon the facilities for steamboats and rafts, and illustrate the difficulty, if not impossibility, of making a low draw-bridge meet all the requirements of river navigation. The difficulties noted here are small compared with what are developed by the same irreconcilable demands elsewhere, where the current is more rapid.

ALTERATIONS TO LESSEN OBSTRUCTIONS TO NAVIGATION.

Sheer-booms.—The Board of Engineers on sheer-booms recommended that a sheer-boom 1,000 feet long be so placed that its lower end would rest against the left rest-pier, with its upper end 650 feet from the right bank, to direct the rafts towed by steamers through the east draw-space when by reason of wind they cannot use the west space.

Widening of the Missouri shore span.—This span is required, by that interpretation of the law which prevents the draw being placed next to the shore, to be 250 feet for the use of rafts. The placing of the abutment 30 feet from the shore takes that much off the span thus required, and compliance with the law necessitates a change. This change can be made by removing the riprap now protecting the shore back to the line of the face of the abutment for half a mile above the bridge, so as to allow the river to scour out its channel up to this line, and rebuilding the abutment on suitable foundations. This will give an excellent passage-way for rafts, but it would allow the bar above the bridge to move 30 feet more toward the Missouri shore, and thus render the use of the left draw-opening more difficult for steamboats. On the whole, it is probably best not to make this change.

Works to control the formation of the bar above the bridge.—Without very extensive works requiring the complete rectification of the river for some considerable distance (2 or 3 miles) it would be impossible to so govern the action of the water as to secure a wider channel between the bar and the Missouri shore. Its width at low water is thus limited by natural conditions to about 400 feet, and we cannot readily increase it.

INCOMPATIBILITIES OF THE LAW FOR BUILDING DRAW BRIDGES.

A little consideration of this case shows the difficulty of framing a law to meet the wants of navigation until the features of the river at the proposed location are ascertained.

If we provide for the steamboat navigation first and for the rafts second, we should (at the site of the Quincy bridge) undoubtedly place the draw-span next the Missouri shore, and it would occupy about 365 feet of the channel.

There would then be no space adjoining for a navigable raft span of 250 feet that could be used in the low-water period, for if even a wider space exists at the bridge site, the projection of the bar above it prevents its being entered. Rafts in such cases must use the draw-opening. If the raft-span is placed next the shore, than the efficiency of one draw-opening is almost completely destroyed at low-water, and the use of the other at times of high wind and dark nights is also made very difficult, if not impracticable. Draw-bridges at such places have therefore to meet irreconcilable wants of navigation. The only thing to do seems to be to make the best location of the draw-openings, and afterward such further provisions for rafts as the case admits of. The wide spans should still be employed in all cases where they might be of use to rafts in stages above low water.

HIGH BRIDGES.

The high bridge is the only kind that can be made here to suit all the wants of steamboat, barge, and raft navigation. A high continuous-span bridge at Quincy was particularly feasible, as the Quincy approach is on high ground, and there is ample room on the west bank to get down without expensive land damages. It should give a clear headway of not less than 57 feet at high water or 77 feet at low-water, and the channel-spans should not be less than 300 feet in the clear.

HANNIBAL RAILWAY AND HIGHWAY BRIDGE.

(Opened for travel in 1871.)

Authority.—This bridge was built in 1871, under act of Congress approved July 25, 1866.

DESCRIPTION OF THE RIVER AND VALLEY IN THE VICINITY.

(See Diagram 25.)

This bridge crosses the river at a point about one mile above the steamboat-landing of Hannibal, Mo., about 17 miles below Quincy. The river at this point is nearly all in one channel, and is very narrow and deep. About one-half mile above (where the river first strikes the bluff on the right bank), the river bends sharply through an angle exceeding 90°; the width is only about one-fourth mile, being one of the narrowest points on the river. It was a noted crossing-place for the Indians in their day.

The low-water width of the river at the point where the bridge is located is about 1,500 feet. Prior to the building of the Sny Carte Levee, the high water spread out from bluff to bluff 6½ miles, but the levee narrowed the high-water width at this point to about 2,300 feet.

The Sny Carte Slough is a small channel, *chénal écarté*, which leaves the main river about 4½ miles above this bridge and joins the river about 33 miles below. This channel was closed and the whole bottom leveed in from the head of the slough to its outlet. The effect of this was to confine all the flood-waters to the main channel, causing their greater volume and velocity. This levee gave away April 17, 1876, at 2 p. m., with the water at 19.6 feet on the bridge-gauge and rising. On the morning of the 18th, the reading was 19 feet on this gauge, while it had not fallen at Quincy. The rise from low to high water is about 22 feet. The slope, as measured by us, near low water, is about 0.4 foot per mile.

SURVEYS.

In November, 1866, we surveyed about 3 miles of river from 1½ miles above to 1½ miles below Hannibal. The low banks were fixed, soundings taken over the whole distance, and the slope measured and observations for volume of discharge made. This was all that could be done until the position for the bridge had been chosen; the water was then about 1.7 feet above low-water. The volume was 52,000 cubic feet per second. In October, 1876 (after the bridge was built), we again made surveys and examinations. The water was six feet above low-water.

DESCRIPTION OF THE BRIDGE.

(See Diagram 27.)

On the Missouri side the bridge is approached through a short tunnel on a 9½° curve, to which the bridge axis is tangent. The line of the bridge is at right angles with the general course of the river. The spans of the bridge commencing at the Missouri side are, first, one 250 feet from centers of piers; then a draw-span 360 feet over all, giving two clear openings of 160 feet; then one span 250 feet, and four of 180 feet each; making the total length of the bridge 1,580 feet. The line of the bridge is prolonged by an embankment of 400 feet from the Illinois end, which is continued by a 6° curve for about 1,100 feet. The Toledo, Wabash and Western Railway continues in a southeasterly direction for several miles in the bottom-lands of the river.

Another railroad, known as the Chicago, Alton and Saint Louis, but lately in the hands of the Chicago, Burlington and Quincy Railroad Company, also uses the bridge. This line leaves the other road 900 feet from the Illinois end of the bridge, and runs to Quincy; it uses the track of the other on the Missouri side of the river.

Substructure.—The substructure, commencing at the Missouri abutment, is first an abutment of masonry resting on the rock of the bank; this abutment is about 25 feet from the low-water line of the river. The draw or pivot pier is of solid masonry, resting on piles. The up and down stream sides are straight lines, 21½ feet long in the direction of the bridge, while the sides next the current are arcs of circles. The width of the pivot at right angles to the bridge axis is about 36 feet. The other piers are of solid masonry, upon a grillage resting upon piles. The piles of the two piers next to the Illinois side were cut off above extreme low water. The stone for these piers was obtained chiefly from the neighboring bluffs, but some came from the quarries near Joliet, Ill. They are of nearly the same form and dimensions as those at Quincy. The guard-rests are cribs filled with riprap. The ends next the pivot are formed to receive and hold in place the floats which occupy the space between them and the pivot-pier. These floats rise and fall with the river. The part of the embanked approach on the Illinois shore, commencing 700 feet from the end of the bridge and leading down the valley for some distance, is used as a part of the Sny Carte Levee. At the time of the high-water of April 17, 1876, this embankment gave away at a point about 1,400 feet below the bridge; this break was about 600 feet wide and scoured out to the depth of 18 feet below the general surface. The levee gave away on the same day at the head of the "Sny Carte."

Superstructure.—The superstructure was built by the Detroit Bridge Company. The draw is wrought iron in all its parts. The other spans are all of wrought iron except the top chords, which are cast. The 180-feet spans are 22 feet high and 21 feet wide. The 250-feet spans are 25 feet high. The draw-span is 25 feet high at the ends and about 35 feet in the center. This draw is turned by a steam-engine located between the trusses above the roadway. The engine drives a horizontal shaft, which drives two vertical shafts (one at each end) that turn the draw. It is claimed by the engineer in charge of this engine that he can handle the draw with ease, even in time of high winds; that he can, by the aid of a friction-brake on the horizontal shaft, stop it in any part of its course; that there has never been a time when a boat could pass the bridge that he has not opened it, and that he has frequently opened it when the wind was so strong that boats would not attempt to run through it. The wagon-way is on the same floor and same level as the railway. Vehicles are not allowed to enter the bridge while a train is on any part of it, and a train is not permitted to enter while a vehicle is on it. The bridge has no sidewalks.

INFLUENCE UPON NAVIGATION.

Steamboats.—The draw-span is 360 feet over all, and gives two clear openings of 160 feet each; the right opening, being more under the protection of the high bluff, and also in line of the channel of the river for some distance above, is the most used. The passage of the bridge by boats at time of low water is attended by but little difficulty or risk; the current, as before stated, is nearly direct for some distance above and below. The maximum velocity, with the gauge 6 feet above low water, is about 3 miles per hour. At high-water the velocity is so strong that boats of small power cannot stem it. At such time it is a very dangerous obstruction, because the draw is located in the swiftest current, needing only a small accident to machinery or a single turn of the wheel too much to cause a serious accident. The case given below of the accident to the *Dictator*, considered one of the most powerful boats on the river, shows how great this danger is. The *Dictator*, a large towboat, with an ice-barge in tow, attempted to pass up through the bridge on the morning of the 17th of April, 1876. When just through the right draw-space, the current struck the bow of the barge, which was some distance in advance of the bow of the steamer (as is the custom in towing there), and swung barge and boat around to the west rest-pier and long span. This 250-feet span was carried away, the boat and barge sunk, and nine or ten lives lost. At the time of this accident the gauge on the draw-pier indicated 19 feet 6 inches, and at 1 p. m. of that day 19 feet 7 inches. The highest water noted is that of 1859, which on this gauge was 22 feet.

Passage of rafts.—The first span next to the right bank is 250 feet from centers of piers, but the abutment is placed on the bank so far back that the full width of the span is only available at high water. At the time of our examination the shore-line was upward of 20 feet outside of the face of the abutment; and a tangent to the shore-line for 1,000 feet above the bridge lay 40 feet outside the face of the abutment, so that the available width between the shore and the first pier was at this stage only 200 feet instead of 240 feet, as it would have been had the abutment been placed on the shore at low-water line. Then the passage of this bridge by rafts would have been much easier, and its passage by boats not made materially worse. The right draw-opening is frequently used by rafts, particularly when towed, because they fear to run close enough to the rocky shore to allow them to use the shore-span, and because, by using the draw-span, they save the trouble of unfastening and refastening to the raft. The passage of this draw-opening by rafts is attended with difficulty, as it is not wide enough and the current sets toward the right bank. While we were making our observations at this bridge, a raft, being towed by a steamer, in attempting to pass through this span, was carried against the west pier after getting more than half-way through. This set of current is caused by the channel crossing to the right bank about 2,000 feet above the bridge. For 1,000 feet above the bridge our observations show that the current is almost parallel with the axes of the piers; but this distance, although probably sufficient for boats to straighten themselves in before passing the bridge, is not sufficient for a raft to have its direction completely changed, so the motion toward the right bank continues down as far as the bridge or farther. This set of the current toward the right bank makes the use of the draw by rafts not towed by steamboats almost impossible, and I believe it is seldom attempted.

ALTERATIONS TO LESSEN OBSTRUCTION TO NAVIGATION.

Sheer-booms.—The Board of Engineers on sheer-booms recommended that a sheer-boom be placed along the right bank above the bridge, with its upper end attached to the shore, the lower end to be moved to the right rest-pier when in position for the passage of rafts through the draw, and to rest against the shore when used for rafts passing through the shore-span. The long span to the right of the draw cannot be made available to its full width without great expense, as the shore is high and rocky. The passage of this bridge by boats might be facilitated by the extension of the left rest-pier 1,000 feet upstream in the line of the current. This extension should be built up above highest water, to allow boats to land against, and drop or slide through the draw. It could also be used to "warp up" by when the current is too strong. This would not interfere with the passage of the bridge by rafts, as the left 250-feet span is not used by them.

HIGH BRIDGE.

A high bridge at this place would require to be placed 55 feet above high-water and 77 feet above low-water. The right bank is high, so it would require only one long approach. If a high bridge were built at this place it should have high spans over the whole low-water river with clear widths of 300 feet, so as to allow boats to use that part of the river in which the current is the most gentle.

LOUISIANA RAILWAY BRIDGE.

(Opened for travel December, 1873.)

Authority.—This bridge was built under authority of an act of Congress approved March 1, 1871, entitled "An act to authorize the construction of a bridge over the Mississippi River at Louisiana, Mo.," and an act approved June 4, 1872, entitled "An act further regulating the construction of bridge across the Mississippi River." The act approved March 1, 1871, required, for the first time on the Mississippi River, that a bridge should have clear draw-openings of 200 feet; and the act of June 4, 1872, required that the proposed location of the bridge should be submitted to the Secretary of War for approval before commencing the erection of the bridge, which requirement was not in previous laws. (See quotations from this law in the account of the La Crosse bridge.)

The matter of plan and location of the bridge was referred to a board of engineers by the Chief of Engineers, General J. H. Simpson, president, and they made a report, dated at Saint Louis, Mo., June 21, 1873, and printed in Annual Report of the Chief of Engineers, 1873, pp. 577–585, requiring a modification of the plan submitted by the chief engineer of the bridge, and the building of certain accessory works for controlling the channel. They also recommended a certain system of lighting the bridge, which matter had heretofore been left wholly in the hands of the bridge authorities. The bridge was built by the Louisiana and Missouri River Railway Company in 1873.

DESCRIPTION OF RIVER AND VALLEY AT THE LOCALITY.

(See Diagram 28.)

The river at the site of the bridge is about 3,700 feet wide at low-water; the high-water width is several miles. An attempt has been made to confine the high-water to a width at this place of about 4,000 feet. This was done by the Sny Carte Levee Company to reclaim a large tract of land between the low-water river and the bluffs, referred to in the discussion of the Hannibal bridge. They constructed a levee from the high ground on the Illinois shore below Quincy to about 8 miles below this space.

The river runs along the foot of the Missouri bluffs from the mouth of Salt River, 2 miles above, to some distance below this bridge. Noix Creek joins the river a few hundred feet above the bridge. The bottom of the river is composed chiefly of fine sand, with gravel and pebbles near the right bank.

SURVEYS.

No surveys were made by us at this place prior to the building of the bridge. We made surveys and examinations at the bridge in October, 1876, when the water was 4.8 feet above low water. The maximum velocity at that time was about 3 miles per hour. The range from low to high water is given by the bridge engineers as 20.5 feet.

DESCRIPTION OF BRIDGE.

(See Diagram 29.)

Commencing on the right bank, the abutment is approached by an embankment on an 8° curve, 450 feet of which is in the low-water river. The first span is 162 feet to the center of the draw rest-pier; then a draw-span 444 feet over all, with two clear openings of 200 feet each; then a span 256 feet; then one of 226½ feet; and then six spans of about 161 feet each from centers of piers, making a total length of bridge of 2,053 feet. From the Illinois end of the bridge there is 1,500 feet of embankment in prolongation of the bridge axis, and then 700 feet on a 6° curve, making 2,200 feet of embankment in all on the Illinois side. At the inshore end of this embankment, the Quincy, Alton and Saint Louis Railroad joins the track of the Chicago, Alton and Saint Louis Railroad. The latter continues in a southeasterly direction across the bottom to the high lands. The former, using what was formerly part of the line of the Chicago, Alton and Saint Louis Railroad, reaches the river-bank at a point about 1,300 feet above the bridge; it continues along the river for about 1,800 feet to the old transfer landing, where the cars of both roads were transferred across the river before the building of the bridge. The Quincy line from this point curves to the right and crosses the bottom-land in a northeasterly direction to the bluffs. The Sny Carte Levee joins the embankment of this line at a point about 1,200 feet from the river. The levee in this part is from 6 to 10 feet wide on top, with varying side slopes of from 1 on 1 to 1 on 2. From this junction to a point on the embankment of the Chicago, Alton and Saint Louis Railway, some distance below the bridge, the railway embankment serves as a part of the Sny Carte Levee.

Substructure.—The piers of this bridge are of masonry, the stone having been obtained from the neighboring bluffs. The abutment on the right bank rests upon piles driven to the bed-rock, which is about 14 feet below low water. It has curved wing-walls, with steps and parapet of hammer-dressed stone. This abutment is 21 feet long and 4¼ feet wide. The piles were prepared for the masonry by laying concrete around and over the heads of them. The right rest-pier is 9 feet wide under the coping and about 25 feet long, with a batter of one-half inch to the foot rise. The upper and lower ends are triangular, the sides of which make an angle of 45° with the sides of the piers, and are at right angles at their intersection, which forms the cut-water. These triangular ends commence immediately below the band or dressed course, which is at highest water-mark. These starlings are finished with sections of cones above the band course. The slope of the upper end of the piers is increased to six inches to the foot, from a point 10 feet below high water to the offset course. The starlings and band course are hammer-dressed. This description applies to all the piers in the river except the pivot. (See Diagram E′.) They are alike in form, and vary only in width, the rest-piers being one foot wider than the others. The foundation of the pivot-pier is of piles driven to bed-rock, as are those under the right and left rest-piers; they were sawed off level with the bottom of the river, and riprap placed around their heads. The masonry was built in water-tight caissons and lowered to the bearing-piles. The bottom of the caissons was a grillage of oak timber, 12 inches by 12 inches. The masonry of the pivot is 39½ feet in diameter on top, with a batter of about one-half inch to a foot. The piers to the left of the draw rest upon piles driven about 20 feet into the sand, and are cut off level with the bottom of the river at that time. The masonry, which was about 2 to 3 feet below low water, rested upon a grillage. The draw-rests are cribs of oak timber below low-water mark; the sides above are of oak plank, triangular in plan; the whole filled with riprap and resting on a bed of riprap. Above the upper draw-rest is a detached ice-breaker, built in the same form and of similar material; it rises only to high water. Between the ice-breaker and the upper draw-rest are four clusters of piles to serve as fenders for boats. Between the guard-rests and pivot are pine floats built of 8 sticks on each side, 4 deep, and 2 wide; these are connected by ties and braced by diagonals. These floats are supplied with posts supported by knees, to act as fenders in snubbing-posts for boats. Above the right rest-pier is a fender which extends 500 feet, flaring on a curve, so as to be 50 feet from the prolongation of the pier at its upper end. This fender has a triangular starling composed of piles driven close together, and filled with stone to about 8 feet above low water. The main part of it is about 16 feet wide, composed of two rows of piles tied across it, each set being about 12 feet apart. On both sides they are connected by wall-strips, one near low water and one some 10 or 12 feet above. On the channel side planks are spiked vertically, close together. Inside of the fender are 16 clumps of piles, with chains and rings attached, for boats to attach to if necessary. The side toward Noix Creek is not planked. The fender piles are sustained by riprap thrown inside, to which has been added much drift-wood from Noix Creek. It is not of proper construction and has sustained much injury. The requirements of the Board of Engineers have not been met.

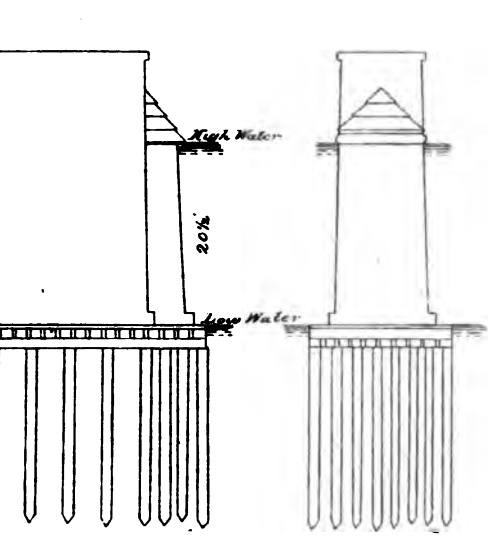
Superstructure.—The superstructure is of wrought iron, except in some minor parts. The bridge over Noix Creek, in the Missouri approach, was built by the American Bridge Company of Chicago; it is 140 feet long. The two long spans and the draw-span of the main bridge were built by the Kellogg Bridge Company of Buffalo, N. Y. The draw-span, at the time of its erection, was the longest in this country (the draw over

Warren's Report Bridging Mississippi River. **Diagram E'.**

Louisiana, Mo.

ELEVATIONS OF PIER 10.

Scale of Feet



AM. PHOTO-LITHO. CO. N.Y. (OSBORNE'S PROCESS)

the Raritan River, New Jersey, erected since, is 472 feet long); its width from center to center of trusses is 18 feet; height of truss at ends, about 31 feet, out to out, and at the center of truss about 40 feet. At 19 feet above the rails, in each panel except the end ones, are longitudinal and transverse braces between the posts and diagonal ties. The posts are of two channel-beams connected by an I beam; these are 12 inches deep in the center, decreasing to 6 inches at the ends. At the center are two inclined posts outside of the regular pair, which serve to carry a portion of the weight to the outside of the turn-table. The upper chord for two panels each side of the center is composed of 4 links; in the next 7 panels toward the end it is composed of links and channel-beams and plates. The ties are rectangular bars; the counter-ties, round rods. All have swivels or turnbuckles for adjustment. The ties and counter-ties extend across two panels. The floor-beams are in pairs, one beam each side of the posts. The 250-foot and 225-foot spans are 31 feet high, the same as the draw at its ends; their width is 14 feet inside trusses and 20 feet outside. The posts of these trusses are composed of two channel-beams connected by an I beam. The ties are of rectangular bars, with eyes through which the pins pass; they are not provided with means of adjustment. The counter-ties are of round rods with swivels or turnbuckles for adjustment; these ties cross two panels. The short trusses were built by the Keystone Bridge Company; they are 20 feet high, with about the same width as the long spans. The diagonals of these spans extend across but one panel. The draw is turned by a steam-engine placed on the turn-table outside of the truss. The usual time required to open and close the draw is from three to four minutes.

Accessory works.—A dike 2,500 feet long, starting from the Illinois shore, about 4,500 feet above the bridge, with its lower end 1,400 feet from the left bank, was built for the purpose of deepening the water between the steamboat-landing and the draw-openings. This was built by the bridge company under requirement of the Board of Engineers. It is built of brush, with riprap to hold it in place, and a few piles to strengthen it in deep water. At the time of our examination, in 1876, with the water 4.8 feet above low-water, it was for the most part submerged.

INFLUENCES UPON NAVIGATION.

The current was measured by us October 12–13, 1876, when the water was 4.8 feet above low water. The form of the sand bar above the bridge was determined at the same time. The conditions can only be appreciated by an examination of the map, but a general description will be attempted. Alongside of the accessory dike built from the left bank was a large sand bar extending below it to within about 1,900 feet of the bridge. It left a channel-way between itself and the right bank of about 600 feet in width in its narrowest part. Below this sand bar is another one, which occupies a breadth of 2,400 feet in the middle of the river. It lies directly above the bridge, and extends down to within 450 feet of the axis of the bridge. This middle-ground shoal leaves deep water on each side of it; that on the Missouri side being the navigable channel. It is only 200 feet wide where the depth exceeds 3 feet at low-water.

The deep water next the Illinois shore is a pocket below the dike and is of no use to navigation. In general, the threads of current on approaching this bar spread out toward each shore and converge as they approach the bridge, everywhere moving in curves until the bridge is passed. The currents make various angles with the axes of the piers, and are scarcely parallel with them in any part of the bridge. The only approach to parallelism is for a short distance in the right draw-opening, where it is confined between the upper guard-rest and the extension of the right rest-pier. The only opening that could then be used by either rafts or boats was the right draw-opening, and the approach to this from above was along the right bank to within about 1,000 feet of the bridge, from which point they approached the opening at an angle, because of having to move to the left about 500 feet. The spans to the left could not be used because of the middle-ground bar. We have here an example of a bridge with the widest draw-openings on the Mississippi River, being one of the most difficult to pass, and furnishing but one practical opening for anything. In high stages the shape of the shores and bed is such that the flow through the draw cannot be much different in direction, but at this time the dike and bars above were submerged, and the flow was more direct through the spans to the left of the draw, making it then the main channel of the river. At the time of the high water in 1876, the first very high water since the building of the bridge, the increased velocity due to the contraction by the bridge scoured out the bottom, particularly under the short spans next to the left bank. This deepening was discovered by those in charge of the bridge. They at once commenced to place riprap about the piers and along the axis of the bridge. This was being done in October, and our examinations showed that nearly the whole bottom between these piers was covered with riprap, and about the piers it appeared above water. The depth between the piers on the axis of the bridge was from 22 to 31 feet, and below the bridge the depth increased from 50 to 57 feet within 150 feet of the piers. The bottom of the piles on which the piers rested were only 27 to 30 feet below the surface of the water, so that the bottom had scoured out below them on three sides of the piers. Notwithstanding their efforts (without any considerable rise in the river), the second pier from the left abutment disappeared on the night of November 6, carrying with it two spans of the bridge. This shows that riprap protection against scour is not efficient when thrown from the bridge. The effect, indeed, is to prevent scouring where the stone falls; but in this case the danger was from the hole made below the axis of the bridge, which the stone did not reach, and which hole finally became so enlarged as to ingulf the whole mass situated above it. To prevent scour in such instances, boats are required from which the stone can be thrown directly into the place where the material is being removed. The effect of the dike built from the left bank has not been what was expected, and the depth of water below, near the left bank, has increased. This is probably owing to the material in the left bank being much finer than on the right, and it does not seem an unreasonable apprehension that if this dike should be carried away at time of high-water the navigable channel might take down the left bank, leaving the draw-openings impassable at low-water. The location of the bridge just below an important landing, as in the case of Burlington, is also objectionable.

ALTERATIONS TO LESSEN OBSTRUCTIONS TO NAVIGATION.

The great narrowing of the water-way by embankments at this bridge forms an exceptional case, and it was a part of the original design. When this plan was submitted to me in May, 1873, I made no objection to this feature of it, but said:

> All experience, on this point, on the Mississippi shows such contraction in width is compensated for by deepening until the area of section and mean velocity are the same as before.

This could not be true if the bridge was built at low water and protected by riprap from scour at high stages. After any such contraction, time should be allowed for succeeding high waters to effect the enlargement before any obstruction is placed in it; not only should time be allowed for this, but the river for a mile or more above should be narrowed and the banks rectified, so as to gradually bring the conditions of the natural river to those at the proposed bridge. This was the course pursued at Saint Louis, to which reference was made by me; there the contraction and rectification of the banks extended through considerable distance, and was gradually effected in the course of a number of years. Such sudden narrowings, as at Louisiana, with riprap protections to prevent scour, produced very abnormal conditions of engorgement, and the want of proper controlling-works above left us without the means of giving permanence to the directions of the currents or the position of the channel. The only thing to do is to supply what has been omitted. In the first place, it is certain that if we do not deepen the section at the bridge to an extent too great for the safety of the present structure, we must widen the water-way. In the modifications which I propose, the Noix Creek span is given to that stream exclusively, and will not be taken into the following consideration of increasing the section of the bridge.

The present section is at low-water 1,750 feet wide, excluding the piers; depth, 10½ feet; area of section, 18,200 square feet; volume, 47,000 cubic feet per second; and a mean velocity of 2.48 feet per second.

It is proposed to increase this width by removing a portion of the embankment on the Illinois side, and by building two spans of 250 feet each in the clear; this will increase the low-water width to 2,250 feet.

We shall then have a new section with:

Width	2,250	feet.
Depth	10½	feet.
Area of section	23,625	square feet.
Volume	47,000	cubic feet per second.
Mean velocity of about	2	feet per second.

At high water the present conditions are:

Width	1,750	feet.
Depth	30½	feet.
Area of section	53,375	square feet.
Volume	480,000	cubic feet.
Mean velocity	9	feet per second.

With proposed increased width:

Width	2,250	feet.
Depth	30½	feet.
Area of section	68,625	square feet.
Volume	480,000	cubic feet per second.
Mean velocity	7	feet per second.

To remove and prevent the reformation of the sand-bar in the middle of the river above the bridge, and to give proper direction to the current, it will be necessary to build new banks and cross-banks running out from the present shore-lines to them. The proposed new shore on the right bank will be on the prolongation in nearly a straight line of the extension of the right rest-pier up to the landing at Louisiana. This new bank will entirely shut off Noix Creek. If it is necessary to use the mouth of this creek for any purpose, it must be done by coming into it from below the bridge.

The line of the proposed new left bank will extend from the proposed new abutment in a line parallel with the new right bank up river about

4,200 feet. The distance between these banks is about 2,400 feet. The cross-banks should be from 300 to 600 feet apart, as experience shows necessary. The work should be begun by building these cross-banks. These should be commenced at the shore, and extended outward by laying down mattresses and weighting them. The bottom layer should be put in over the whole distance at once to prevent scour at the ends, and they should be raised at such rates as the observed effects call for. The portion of the present wing-dam above the bridge, between the proposed new banks, should be removed. It is unnecessary to enter into details of this operation here. The frequent failure of these cross-banks or jetties in this country has been due to their being placed too far apart. There may be no necessity of building the new left bank more than to put a T at the end of the cross-banks; and their heights there need not exceed the height of the present bottom land. The new longitudinal bank on the right side should, however, extend 4 feet above the highest water, so as to produce no cross-currents into or out of Noix Creek.

Similar regulation of the river to that proposed here is used at Kulenburg Bridge, in the Netherlands. The difficulty of making a suitable draw-bridge at this point will probably lead to the adoption of a high bridge in its place.

Sheer-booms.—The Board of Engineers recommended as an immediate alleviation of the difficulties experienced in passing rafts, that the bulkhead in extension of the right rest-pier be continued up river at least 500 feet, and this line extended 820 feet farther by a fixed boom, its upper end 300 feet from the shore at ordinary low water.

HIGH BRIDGE.

A high bridge at this place would have to be placed 57 feet above high-water. It would have an easy approach from the right bank and a high approach on the left bank. It should have at least three high spans, with clear openings of not less than 300 feet each.

SAINT LOUIS ELEVATED RAILWAY AND HIGHWAY BRIDGE.

(Opened for travel in July, 1874.)

Authority.—This bridge was built under provisions of sections 11 and 12 of the act approved July 26, 1866, and act approved July 20, 1868.

DESCRIPTION OF THE RIVER AND VALLEY AT THE LOCALITY.

The Mississippi has been subjected to great artificial contractions at Saint Louis, beginning in 1838, when dikes were commenced to prevent the enlargement of the channel east of Bloody Island and improve the one on the other side. These works were added to from time to time, and in 1850 a low-water stone dam was built across the channel east of Bloody Island, which, however, was afterward carried away. In 1852 the present high-water dam connecting Bloody Island with the Illinois shore was built and made a highway. Prior thereto this channel had become so filled up that water did not run through till the river was 13 feet above low water. (See report of Col. W. E. Merrill, Major Engineers.) The site of Saint Louis is mainly above overflow. The shore in places is of rock. Considerable portions of the river front have been graded, sloped, and paved with stone. Bloody Island, now East Saint Louis, has been partly raised above overflow, and the river front also sloped and paved.

The low lands in Illinois known as the "American Bottom," about 6 to 8 miles wide, are protected from overflow. The whole volume of the river is therefore confined to a narrow channel about 1,200 feet wide at low water and 1,900 feet at high water. The slope of the water surface, at both high and low water, is on an average about .65 foot per mile. The maximum velocity and volume have not been determined. The ordinary high floods are about 35 feet, the greatest known 41½ feet, above low water.

The city directrix is 33½ feet above low water. The scouring in time of floods and ice-gorges is very great. The bed-rock lies about 90 feet below the surface of low water on the Illinois side, and probably underlies the whole "American Bottom" at about that level. Surveys were not made by me at this place, all the important information to be obtained in this way having been determined by other officers of engineers. The wide spans and piers parallel with the current give ample space on the water, but the headway is insufficient to allow the large steamboats to pass it at high water. (See discussion in Chapter III.)

DESCRIPTION OF THE BRIDGE.

The information available for a description of this bridge is contained in a report of the engineer-in-chief in 1868, and the modifications of it given in his report in 1870, together with the discussions in regard to it printed in the Transactions of the American Society of Civil Engineers. It is probable that we shall, in due course of time, have a full account of the bridge in detail, and of all the operations connected with it; but it has such an important relation to the navigation of the Mississippi that it is thought best to attempt to give a general idea of it here. The abutments are placed on the margin of the water at ordinary low stage, with two piers in the channel-way. The three spaces thus left are spanned by circular segment arches. The middle one has a chord of 515 feet and versed sine of 47½ feet. The lowest part of the arch at the springing line is 7½ feet above the city directrix, or at the level of high-water of 1844. The crown of the arch is therefore 55 feet above the city directrix. The chord of the side spans is 497 feet, and the versed sine 43 feet 10 inches. The springing lines at the abutments are 18 inches lower than at the piers, so as to lower the crown about 9 inches, leaving the height at that point 50¼ feet above the directrix.

Mr. Theodore Cooper says (Trans. Am. So. Civ. Engrs., vol. iii, p. 239):

> Each span is composed of four arched *ribs* spaced respectively 16¼, 12, and 16¼ feet apart from center to center (Figs. 3 and 4). Each of these ribs is composed of two lines of tubes (called the upper and lower *member* according to their position), spaced 12 feet apart between centers of the tubes. The several tubes are about 12 feet long. The upper and lower members of each rib are connected together by a system of triangular bracing. The first or skew-back tubes of each member are rigidly fastened (screwed into) the large wrought-iron skew-backs, which in turn rest upon the bed-plates set into the masonry, the whole being firmly anchored to the piers or abutments by large steel anchor-bolts. The several tubes forming one line or member are rigidly connected at their ends by grooved couplings (Fig. 5), carefully fitted to grooves cut on the ends of the tubes. The couplings are made in halves with flanges for bolting them together. Through the center of each coupling and the ends of the tubes passes a taper pin-hole for the steel pin, upon which the braces and cross-stays are attached. All joints were made as nearly perfect as the best mechanical appliances would permit.

The section of the tube is a circle. Each tube has an envelope of steel one-quarter of an inch thick. There are six steel staves in each tube. Their thickness is as follows, beginning at the springing lines: Staves in first tube, $2\frac{1}{8}$ inches; second tube, $1\frac{7}{8}$ inches; third, $1\frac{5}{8}$; fourth and fifth, $1\frac{7}{16}$ inches; thence to the center $1\frac{3}{16}$ inches.

The two lines of tubes, forming a single vertical rib, are united together and braced by a single triangular system of vertical bracing, formed of flat bars of wrought iron secured to the tubes by steel pins passing through the center of each coupling. Each individual tube is straight, the curvature of the rib being accomplished at the junction of these individual members.

In the Report of the Chief Engineer, 1868, pp. 32–33, it is stated that—

> A granite course 8 feet in thickness will be laid through the channel-piers and in the abutments, to receive the skew-backs or heavy cast-iron plates against which the ends of the arches will rest.

In the report for 1870 the arched ribs are so modified that there are but two tubes in each 12 feet apart from centers, instead of 9 feet as first designed. The granite course was probably increased to a corresponding thickness. According to the drawing in the report for 1870 the thickness through the piers at the springing line of the lower tubes is about 31 feet, so that the distance from abutment to abutment at the springing lines is about 497 + 31 + 515 + 31 + 497 = 1,571 feet.

The batter of the masonry appears on the drawings about 12 upon 1, and as the springing lines of the center span are 41 feet above low water (besides there being an offset of 1 foot), the width of the center span at low water is reduced by about 9 feet; or is about 506 feet clear of masonry. The side spans are reduced by about the same amount at low water, so that these spans are 488 feet in the clear at the level of low-water. The drawing shows the levee occupying about 30 feet of this shore-span, so that there is more space at low water than the river-banks afford.

Roadways and lateral bracing.—The roadways are supported by vertical wrought-iron posts of "cruciform section" rising over the upper tubes at the points where they are united with the lower ones by the triangular system of bracing. The two center arched ribs in each span are placed 12 feet apart from center to center. These two arches are thoroughly braced against lateral motion, both at the upper and lower tubes. The outside arches are $16\frac{1}{2}$ feet from the middle ones. The level of the railway in the middle portions of the span is placed near the lower tube, and this compelled a modification of the bracing used in the middle arches, wherever the upper arch rose above the railway-track. At these portions the lateral bracing is confined to the upper and lower roadways.

In the report for 1868 it is stated that—

> The upper roadway is 34 feet wide between the foot-walks. The latter are each 8 feet wide, making the bridge 50 feet wide between railings.

Captain Eads states (in Trans. American So. Civ. Engrs., vol. iii, p. 322) that the cost was increased by widening 4 feet.

> The railway passages below the carriage-way will each be 13 feet 6 inches in the clear and 18 feet high, and will extend through arched openings of equal size in the abutments and piers. The railways will be carried over the wharves on each side of the river on five stone arches, each 26 feet wide, and will be inclosed throughout this distance by a cut-stone arcade of twenty arches supporting the upper roadway. After passing over those stone arches the railways will be carried through the blocks between the wharf and Third street on brick arches into the tunnel at Third street and Washington avenue. Over the intervening streets they will be carried on wrought-iron trusses. On the Illinois shore the railways will curve off to the north and south immediately after crossing the last one of the stone arches, and, with a descending grade of 1 foot in 100, extending about 3,000 feet, and supported on trestle-work part of the way,

> they will reach the grade of the railways in East Saint Louis. The carriage-road will begin to descend with a grade of 5 feet in 100 at the eastern end of the bridge, immediately after the railway-tracks curve away from the latter, and will conform at Third street, in East Saint Louis, to the grade of that street. On the Missouri side the carriage-way will be continued over the railway-tracks from the bridge to Third street on a level grade.

The railway grade between the two abutments is a little less than 1 in 100. The railway gradients of the approaches are 1 in 100, and some trouble has been experienced in the crawling of the track under the action of the driving-wheels of the special locomotives employed, as has been the case with other bridges with a grade of 1 in 100.

The superstructure was erected by the Keystone Bridge Company, under the superintendence of Mr. Walter Katté. It was done without false works, by suspending the tubes from the towers with tie-rods, and employing temporary anchorages on the banks of the river.

Foundations of the piers and abutments.—The foundations all rest upon the bed-rock of the river. The Saint Louis abutment with much difficulty was placed, by means of an ordinary coffer-dam, upon the bed-rock, about 13 feet below low-water mark. The others were sunk to the bed-rock by means of inverted caissons and the plenum pneumatic process. Great ingenuity, boldness, and skill were displayed in this work, which succeeded with some loss of life, inseparable from the great air-pressure necessarily employed. The depths below extreme low water to bed-rock were, for the Saint Louis pier, 58 feet; for the east pier, 86 feet; for the east abutment, 94 feet. The water was rarely less than 5 feet above extreme low water, and it was important in economy of time to work with the water as much as 18 feet above low water. It is probable, however, that this increased pressure could not be generally endured when the pier-foundations had approached the bed-rock at the greatest depth. The foundations of the shore approaches in the Saint Louis side were placed on rock. On the Illinois side they rest on piles cut off at about the level of low water. Considerable difficulty was found in the yielding nature of the silt which had filled in the old channel east of Bloody Island, and only the lightest trestle approaches could be readily built there.

Masonry.—Most of the stone used is the magnesian limestone of Grafton, but there is a course of ashlar of granite in all the parts exposed to running ice from 4 feet below low water up to the highest floods.

> *Loads.*—The arches have been designed with sufficient strength to sustain the greatest number of people that can stand together upon the carriage-way and foot-paths from end to end of bridge, and at the same time have each railway-track below covered from end to end with locomotives.—(Report of Engineer-in-Chief for 1868, p. 33.)

On next page of this report it is stated:

> The weight of the three spans and the maximum load they are designed to bear is 7.2 tons per linear foot.

On the diagrams of strains accompanying this report the weight of the structure is taken at 1 ton per linear foot per rib, leaving but 3.2 tons for the moving or live load. In considering the moving loads in devising the new Rock Island bridge, I was advised to allow 2,500 pounds per foot for a single-track railroad, and 100 pounds per foot for each square foot of common road and sidewalk. This allowance would have required 5,000 pounds per foot for a double-track railroad and 5,000 pounds per foot for a highway 50 feet wide, or a moving load of 5 tons, being as 25 to 16 over that provided for here. Both tracks filled with engines would weigh about 5,000 pounds per foot, leaving out of the 3.2 tons, or 6,400 pounds live load, but 1,400 pounds per foot for the upper roadway packed with people, which would be only 28 pounds per linear foot. This is evidently too small an allowance.

The bridge designed by the convention of civil engineers, in the year 1867, was for a single-track railway, moving load 2,184 pounds; two wagon-ways, 14 feet wide each, moving load 100 pounds per square foot, or 2,800 pounds per linear foot; two sidewalks, 8 feet wide each, moving load 70 pounds per square foot, or 1,120 pounds per linear foot, making a total moving load of 6,104 pounds per linear foot, which is almost as much as the present bridge allows for wider common roadway and one more railway.

Mr. Eads, in his discussion in the American Society of Civil Engineers, page 322, states the cost as follows:

Masonry—abutments, piers, tools, and machinery	$2,364,452 26
Superstructure, excluding approaches	2,234,655 42
General items of engineering and contingent account	400,000 00
Cost, excluding approaches	4,999,107 68
Cost for everything, including approaches, salaries, rents, engineering, steam and street railways, gas and water pipes, all of its approaches, losses by failure of contractors, extra compensation and bonuses to expedite work (but excluding tunnel and land damages)	6,680,331 47
Additional cost of bridge, consisting almost wholly in items of discount, interest, and commissions on bonds, charters, legal expenses and similar expenditures, including $1,086,000 for real estate and right of way	6,000,000 00

The opinions of engineers generally are unfavorable to this form of bridge.

(1) It is of a form that interferes too much with navigation. (Report of Army Engineer Board.)

(2) It is not considered a good pattern for economy.[*]

(3) It is subject to great strains due to temperature.[*]

(4) It is difficult to calculate the strains upon different parts and apportion the dimensions of parts.[*]

This bridge has had a large influence upon the question of bridging navigable channels, which is shown in the next chapters to this report. (Chapter V.)

Tabulated statement of bridges on the Mississippi between Saint Paul, Minn., and Saint Louis, Mo., authorized but not built.

Bridges.	Act approved—	Remarks.
HIGH OR DRAW BRIDGES.		
Red Wing, Minn	June 10, 1872	
La Crosse, Wis	Feb. 21, 1868	
Savanna, Ill	Apr. 1, 1872	
Clinton, Iowa	Apr. 1, 1872	By act approved June 6, 1874, may be built as a ponton bridge.
Muscatine, Iowa	Apr. 1, 1872	
Fort Madison, Iowa	May 25, 1872	
Warsaw, Ill	May 17, 1872	Authority expired by limitation.
Quincy, Ill	May 17, 1872	
PONTON BRIDGES.		
La Crosse, Wis	July 6, 1876	Highway bridge.
Dubuque, Iowa	Mar. 3, 1873	Do.
Clinton, Iowa	June 6, 1874	Railway bridge: it may be built under this act or under the act of April 1, 1872.

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[*] Discussion in Am. Soc. Civ. Engrs.

CHAPTER V.

GENERAL HISTORY OF BRIDGING THE NAVIGABLE WESTERN RIVERS IN ITS RELATION TO THE LAWS; TO THE DECISIONS OF THE UNITED STATES COURTS; TO THE DEBATES IN CONGRESS; TO THE OPINIONS OF EMINENT ENGINEERS, ETC.; GIVEN IN A CHRONOLOGICAL ORDER.

HISTORY OF THE BRIDGE ACROSS THE OHIO AT WHEELING—HISTORY OF THE FIRST BRIDGE ACROSS THE MISSISSIPPI AT ROCK ISLAND—ABSTRACT OF DEBATES IN CONGRESS PRECEDING THE AUTHORIZATION OF BRIDGES ACROSS THE MISSISSIPPI RIVER—ABSTRACT OF DEBATES IN CONGRESS LEGALIZING THE BRIDGE ACROSS THE MISSISSIPPI AT CLINTON—HISTORY OF BRIDGING THE MISSISSIPPI AT SAINT LOUIS—QUOTATIONS FROM DECISIONS OF THE UNITED STATES SUPREME COURT FOR INJURIES SUSTAINED AT THE SAINT PAUL RAILWAY DRAW-BRIDGE—MEMORANDUM UPON BRIDGING THE OHIO RIVER SUBSEQUENT TO THE WHEELING BRIDGE CASE—MEMORANDUM UPON MISSOURI RIVER BRIDGES—ABSTRACT OF LAWS FOR BRIDGING THE OHIO, MISSISSIPPI, AND MISSOURI RIVERS.

Introductory remarks.—The information presented in this chapter consists of notes, &c., obtained by reading the Statutes at Large; the decisions in the United States courts; the debates in Congress, and the reports of engineers, together with correspondence in regard to points of interest upon which information was wanted. This was done at first for my own use, but it appeared to me when this report was about finished that it might contain information of value to others, who may have to consider this subject of bridging navigable waters, either as engineers or law-makers. I have therefore thrown these notes together in a general chronological order, and for want of a more appropriate term have designated it as a general history of the bridging of the navigable Western rivers, although it cannot but fail to rise to the dignity which the name implies. In chapters II, III, and IV of this report I have treated the subject almost purely in its relations to engineering and navigation. The present chapter, in a measure, exhibits the relations which these things have held to other interests.

HISTORY OF THE BRIDGE ACROSS THE OHIO AT WHEELING.

The first bridge over important navigable Western rivers was that across the Ohio River at Wheeling, built in 1848–'49. It occasioned a suit for injunction which came before the United States Supreme Court, the reports of which give us all the information we could desire up to that time. The whole subject is here so thoroughly considered that it is certain that no reasonable view could be taken of the subject at that time that was not then presented and discussed. It naturally furnishes us a good point of beginning.

From these reports we learn that the National Road, as it was often called, reached the banks of the Ohio at Wheeling, where the passage between Wheeling and Zane's Island by ferry was found dilatory and precarious by day and ordinarily useless at night, being frequently impassable on account of ice, and that a bridge being much desired by the people of Ohio and Virginia, acts were passed in 1816 by both those States authorizing a bridge across the river at Wheeling, but which provided that if such bridge should be so constructed as to injure the navigation it should be treated as a public nuisance and be liable to abatement as other public nuisances. Ten years were allowed for the completion of the bridge.

By an act of Virginia in 1836 certain facilities for the reorganization of the bridge company were conferred, and by the consent of Ohio the time was extended ten years longer. This company constructed a continuous truss-bridge from Zane's Island to the Ohio or western shore.

In March, 1847, the legislature of Virginia passed an act reviving and continuing certain parts of the former acts, and providing for the reorganization of the corporation, "with power to erect and keep a wire suspension-bridge on and from Zane's Island to and upon the main Virginia shore or bank at the city of Wheeling."

This act contained the proviso—

> That if the said bridge shall be so erected as to obstruct the Ohio River, as navigated in the usual manner by such steamboats and other craft as are now accustomed to navigate the same, when the river shall be as high as the highest flood therein heretofore known, then unless, upon such obstruction being found to exist, such obstructions shall be immediately removed or remedied, the said last-mentioned bridge may be treated as a public nuisance and abated accordingly.

A petition for a law authorizing a bridge at Wheeling was before Congress in 1836, and urged during both sessions of the Twenty-fourth Congress without success. The matter was reported upon by Lieut. George Dutton, Corps of Engineers, and Lieut. John Sanders, Corps of Engineers (House Doc. No. 993, Twenty-fifth Congress, June, 1838).

> They presented a plan for a suspension-bridge across the Ohio River, having for its basis a strict regard to the rights of navigation. * * * This plan proposed a span of 500 feet in width and the height of the highest chimney then known, and in order to provide for any change or improvement in steamboats, the floor of the bridge was to be movable, so as to allow the passage of boats. [Argument of Mr. E. M. Stanton before United States Supreme Court, Howard, vol. 13.]

It was stated that the highest flood, that of February, 1832, was extraordinary, and rose 44½ feet above low water at Wheeling; that the highest usual flood does not exceed 38½ feet, but will not average 35 feet for spring floods nor much exceed 29 feet.

It was claimed by the bridge company—

> That for all useful purposes the pipes of steamboats need not exceed 47 feet above the water, and that if the draught was not sufficient, blowers might be added. That chimneys might have hinges on them so that they could be lowered.

The steamboatmen claimed that the existing heights of chimneys, in some cases 84 feet 7 inches above the water, were necessary; and that their large diameter, over 5 feet in some cases, and their weight (the two together, in some cases, weighing 4 tons) made it impracticable to lower them.

Steamboats of the largest class then running to Pittsburgh were on an average 230 feet long and over 50 feet wide. The pilot-houses stood 48 feet above the water.

The bridge from Wheeling to Zane's Island consisted of a single span of 1,010 feet from center to center of the supporting towers, the height of which was claimed to be 90 feet at the eastern abutment, 93½ feet at the highest point, and 62 feet at the western abutment above low water.

The bridge was begun in 1848. While it was in the earlier stages of construction, notice was served upon the company of a suit to enjoin them July 28, 1849. This suit was brought in the United States circuit court sitting in Philadelphia. Mr. Justice Grier, one of the judges of the United States Supreme Court sitting, transferred the case, on August 16, 1849, to the Supreme Court, "because the question of the plaintiff's right to prosecute this is new and involves the jurisdiction of the court."

On January 11, 1850, the legislature of the State of Virginia passed an act "to the effect that the suspension-bridge as erected was of a lawful height and in conformity with the intent and meaning of the proviso in the enabling act passed in 1847."

The first report of the case, in the United States Supreme Court, was of the hearing at the January term in Washington in 1850, and is reported in Howard, vol. 9, pp. 647–659, Pennsylvania *v.* Wheeling and Belmont Bridge Co. et al. On May 29, 1850, the court ordered the cause to be referred to the Hon. R. Hyde Walworth, ex-chancellor of the State of New York, as a commissioner of the court, thus far affirming the question of jurisdiction, to which Mr. Justice Daniels dissented.

The commissioner was to take such further proofs in the cause as the counsel for the respective parties may see fit to produce before him. The commissioner was also directed, if the bridge should appear to be an obstruction to the free navigation of the Ohio River, to state—

> What changes or alterations in the construction and existing condition of the said bridge, if any, can be made consistent with the continuance of the same across said river that will remove the obstruction to the free navigation.

The commissioner was to report at the next stated term, December, 1850.

At the December term, 1850, on the 13th of that month, the commissioner's report was received, and the court ordered that the case be continued to the next term, with leave to each party to file exceptions to the commissioner's report on or before the first Monday of July, the exceptions to stand for argument on the second Monday in December, 1851. If no exceptions shall be filed by either party, then the case to stand for final hearing on the day last mentioned. (See Howard, vol. 11, pp. 528, 529.)

The report of the case at the December term of 1851 is given in Howard, vol. 13, pp. 518–628.

The printed report (more than 700 pages) of the commissioner, with the report of his engineers, and the evidence taken, was presented. Copies of this report are rare. It was printed by George White, at Saratoga Springs, N. Y., in 1851. His decision was that the bridge was an obstruction to free navigation of the Ohio by vessels propelled by steam, but not by any propelled by sail. That the bridge should be changed by raising "the cables and flooring in such manner as to give a level headway at least 300 feet wide over a convenient part of the channel of not less than 120 feet above the zero on the Wheeling water-gauge." As built, the highest point was about 92 feet above low-water level, and it descended each way toward the shores 4 feet in 100 feet, so that, taking the highest point as a center of the highest space, 100 feet wide, it is at its extremities only 90 feet above low water.

After a full hearing from learned counsel on both sides, a majority of the court decided that—

> The bridge obstructs the navigation of the Ohio, and that the State of Pennsylvania has been and will be injured in her public works in such manner as not only to authorize the bringing of this suit, but to entitle her to the relief prayed for.
>
> * * * * * * *
>
> And on a full view of the evidence we are brought to the conclusion that an elevation of the lowest parts of the bridge for 300 feet over the channel of the river, not less than 111 feet from the low-water mark, will be sufficient, the flooring of the bridge descending from the termini of the elevation at the rate of 4 feet in the 100 feet in width, and will enable those whose chimneys are 80 feet high to pass under the bridge when the water is 30 feet deep from the ground, leaving the tops of the chimneys 2 feet below the lowest parts of the bridge. If this or some other plan shall not be adopted which shall relieve the navigation from obstruction on or before the 1st day of February next (1853), the bridge must be abated.
>
> We do not deem it necessary to provide against the floods, which seldom occur, and which, when at the highest, overwhelm the lower parts of the cities and towns on the banks of the Ohio, and necessarily suspend, for a short time, business upon the river.

To this decree Mr. Chief Justice Taney and Mr. Justice Daniels dissented, denying jurisdiction in the absence of more specific legislation by Congress, and for other reasons.

Upon the opinions being pronounced, the counsel for the defendants suggested to the court that some other change might be made than that directed, which would be less expensive to the bridge company and equally satisfactory to the public, and submitted four alternative propositions for consideration. These the court received, and on March 1, 1852, directed Mr. William J. McAlpine, "the engineer, who acted under the commissioner," to report upon them. This report was made May 8, 1852, and is given in the Howard Report, vol. 13, pp. 615–621, and made the subject of further argument, which, however, is not reported.

Mr. McAlpine reported that two sliding draws might be constructed across the western channel, over which there was an ordinary low truss-bridge in continuation of the suspension-bridge across the main channel, giving clear opening of 200 feet, at an expense not so great as raising the suspension-bridge according to the decree of the court; that clear draw-opening of 300 feet might be made by rebuilding this part of the bridge, but that it would cost more than raising the suspension-bridge.

The court adopted his view that—

> A draw can be constructed on the wooden bridge over the western channel of the river which will, under ordinary circumstances, offer a safe and convenient passage for the largest class of boats which ply from Pittsburgh, having chimneys 80 feet high.

A draw of 200 feet was proposed, and one less than that would not answer the public demand.

Without changing the former decree, it was left an open question for the bridge company to adopt this change instead of the other before the 1st day of February, 1853, "on which day the plaintiff may move the court on the subject of the decree, and of the proposed alteration in the western channel, which being before the court will enable them to act in the premises as the law and equity of the case may require."

Mr. Chief Justice Taney and Mr. Justice Daniels dissented, not only as to the jurisdiction of the court, but thought a draw giving a clear width of 100 feet at the utmost would be ample. The continuation of the case of this bridge is in 18 Howard, pp. 421–463.

On August 31, 1852, Congress enacted—

> That the bridges across the Ohio River at Wheeling, in the State of Virginia, and at Bridgeport, in the State of Ohio, abutting on Zane's Island in said river, are hereby declared to be lawful structures in their present positions and elevations, and shall be so held and taken to be, anything in the law or laws of the United States to the contrary notwithstanding.
>
> That the said bridges be declared to be and are established post-roads for the passage of the mails of the United States, and that the Wheeling and Belmont Bridge Company are authorized to have and maintain their bridges at their present site and elevation, and the officers and crews of all vessels and boats navigating said river are required to regulate the use of their said vessels, and of any pipes or chimneys belonging thereto, so as not to interfere with the elevation and construction of said bridges.—(10 Stat. at Large, 112.)

The bridge company, therefore, took no measures to comply with the decree of the Supreme Court.

In the summer of 1854 the bridge was blown down by a violent storm, and the company were preparing to rebuild it according to the original plan when the next step in the history of the case was taken.

A notice was served upon the bridge company, and pursuant thereto the attorney-general of Pennsylvania and counsel appeared before the Hon. R. C. Grier, one of the justices of the Supreme Court, at chambers, on the 26th of June, 1854, and moved for an injunction, as prayed for in a supplemental bill then exhibited. On hearing the bill and affidavits, the injunction was granted.

The writs of injunction were served, yet they proceeded to erect the bridge notwithstanding, and it was completed in November.

At the December term, 1854, the complainant filed a motion for a sequestration against the company for a contempt of court in disobeying the injunction, and a motion for an attachment against the officers personally for their contempt in disobeying the injunction.

A majority of the court were of the opinion that the act of Congress afforded full authority to the defendants to reconstruct the bridge, and the decree directing its alteration or abatement could not, therefore, be carried into execution after the enactment of this law. The motion for the attachment was denied and the injunction dissolved.

Mr. Justice McLean and Mr. Justice Grier dissented, and each gave an opinion. Mr. Justice Daniels concurred, and gave a separate opinion about the question of original jurisdiction.

There were other suits against the bridge company for damages, but all fell upon the passage of the act of Congress legalizing the bridge and the decision of the Supreme Court in regard to it. In this respect the law was regarded as retroactive.

The condition of this bridge and its effect upon navigation were reported upon by the Board of Engineers, composed of myself and General Weitzel and Colonel Merrill, Corps of Engineers, in 1870. (See Annual Report Chief of Engineers, 1871, p. 405.)

HISTORY OF THE FIRST BRIDGE ACROSS THE MISSISSIPPI AT ROCK ISLAND.

This was a railway draw-bridge, opened for travel in 1856, and torn down in 1872. It was probably the worst obstruction to navigation that any bridge ever occasioned. Happily it now exists only in history, but that history is instructive.

This bridge was built between the years 1853 and 1856, to connect the Chicago and Rock Island Railroad in Illinois with the Mississippi and Missouri Railroad in Iowa, this latter extending from Davenport to Iowa City, a distance of about 55 miles.

Authority to build.—A railroad-bridge company was incorporated by the legislature of the State of Illinois—

> To build, maintain, and use a railroad-bridge over the Mississippi River, or that portion within the jurisdiction of the State of Illinois, at or near Rock Island, in such manner as shall not materially obstruct or interfere with the free navigation of said river, and to connect by a railroad, either in the State of Illinois or Iowa, terminating at or near said point, * * * * *
>
> *Provided*, The said company shall commence said bridge within two years, and shall complete the same within six years from the passage of this act.

This act was approved January 17, 1853, and went into effect immediately.

There was much difference of opinion as to the extent of the jurisdiction of the State of Illinois, but no one claimed it to extend beyond the center line of the deepest navigable channel between Rock Island and the Iowa shore. It does not appear that any special authorization to extend the work from the Iowa shore to this channel-line was obtained from the legislature of the State of Iowa. In the hearing of the bill requesting an injunction to restrain the Mississippi and Missouri Railroad Company from rebuilding or adding to the piers, before Judge

John M. Love, in the United States district court, at Burlington, Iowa, in August, 1858, it is stated:

> The said Mississippi and Missouri Railroad Company own the land on the Iowa shore where the said bridge terminates, and have procured the right of way and have constructed a railroad from said bridge to Iowa City, a distance of about 55 miles. That as a color of right for the establishment of said bridge and using the same, they have procured a deed of conveyance from Antoine Le Claire, the former owner of the land on the bank of the river where said bridge terminates, thereby conveying to said company the land to the center of the main channel of said Mississippi River, including the identical ground upon which said piers are built on the Iowa side of the main channel of said river.

In the answer, the defendants set up no other claim of right to build the bridge over the Iowa part of the river, so that the above quotation probably represents this feature of the right of way correctly.

Authority contested but sustained.—The route, as located, extended over the island of Rock Island, then and now belonging to the general government, and held as a military reservation, and soon after the act of incorporation by the general assembly of Illinois, in 1853, the Secretary of War directed the United States district attorney of that State to apply for an injunction. The principal point made in the bill was against the right of way across the island, and the question of obstruction to navigation only received consideration incidentally. The depositions by affidavit and argument were made before Judge John McLean, associate justice of the United States Supreme Court, at Chambers, at Washington City. The opinion was delivered at Chicago in July, 1855, and the case is reported in the sixth volume of McLean's Reports, page 517. The injunction was refused and the construction of the bridge went on, and it was completed, as already stated, in the winter of 1855–'56, so that on the opening of navigation in 1856 steamboats were compelled to pass through the draw-openings of the bridge.

Injuries and suits for damages.—Serious delays and damages to vessels in passing the east draw-opening (the other being impracticable) at once began, and many rafts were broken up by the piers. On May the 6th the new steamboat Effie Afton, in passing the draw, was caught upon the head of one of the piers, careened over so as to upset one of the stoves on board of her, from which she took fire and was destroyed. One of the spans (they being wooden Howe trusses) was burned with her. Fortunately there was no loss of life. Many other vessels were damaged during this year.

A suit for damages against the bridge company was brought by the owners of the Effie Afton and tried at Chicago, Ill., in September, 1857, the Hon. John McLean, associate justice of the United States Supreme Court, presiding. The jury could not agree and were discharged.

On the 4th of January, 1858, the United States House of Representatives passed a resolution that the Committee on Commerce inquire if the bridge at Rock Island is a serious obstruction to navigation, and, if so, to report what action, if any, on the part of the government was necessary. Mr. E. B. Washburne, chairman, submitted the report April 15, 1859, printed as H. R. Report No. 250, Thirty-fifth Congress, first session. This report states that it is the opinion of civil engineers who have seen the bridge that its position is very bad; unlike any they have before seen; and that it cannot be otherwise than a very serious obstruction to the passage of boats. It states also—

> That the number of passages by steamers at this point is about one thousand a year, each of them having on board, without doubt, many passengers and valuable freight.
>
> If, as the friends of the bridge assert, the railroad interests need a bridge near that point, surely it should be constructed in the best possible manner, and so as to afford

the best water-way and easiest passage for the very large number of boats passing there. We think the company have failed to do this, and that any bridge is a *material obstruction* which is susceptible of being essentially improved.

This report concludes as follows:

> From the evidence presented before your committee, they cannot doubt but that the bridge, as at present constructed, is a material and dangerous obstruction to the navigation of the Mississippi River, but they believe that the courts have full and ample power to remedy any evil that may exist in that regard. At present they are disinclined to recommend any action by Congress in the premises; but whether at some future time it may not be expedient to direct the proper law officers of the government to proceed against the bridge, this committee will not now undertake to determine.

Appended to this report is an abstract of the *Effie Afton* trial; also opinions adverse to the bridge of Capt. M. C. Meigs, Corps of Engineers; General Joseph G. Totten, Corps of Engineers; Mr. Charles Ellet, jr., civil engineer; and the presidents of several insurance companies.

The bridge-piers, as first built, were very weak structures, mostly timber cribs filled with stone. They were not only temporary in the kind of material, but were not of proportions as to weight and strength to withstand the impact of ice and other floating bodies in the swift current in which they were placed, although resting on the rock-bed of the rapids. Hence it was that in 1858 it became necessary to replace and strengthen some of the piers on the Iowa side of the channel. A vigorous effort was made by the navigation interests to obtain an injunction and prevent the placing of any more stone or enlargement of the piers. The case known as Ward *vs.* The Mississippi and Missouri Railroad Company was presented and argued before the Hon. John M. Love, district judge, in the United States district court, district of Iowa, opening at Burlington on August 19, 1858. The plaintiffs supported their case by elaborate affidavits from eminent civil engineers and skillful pilots and other navigators, to the effect that the structure was a most serious and unnecessary obstruction to navigation. The judge decided, for reasons given, not to grant the injunction.

The plaintiff immediately filed a supplemental bill, setting forth that since filing the original bill there was reason to believe the defendants were preparing to increase the obstructions by new works not stated in their answer to the original bill, and praying that they be enjoined from doing anything not set forth in that answer. The hearing upon this supplemental bill was adjourned till November 16, at the request of the defendants, they stipulating that no cribs or other structures should be placed in the river until this hearing. Report of the suit, including the testimony, was published by the Missouri Republican, and printed in pamphlet form by George Knapp & Co., Saint Louis, Mo.

At the request of certain Senators and Representatives in Congress, the Secretary of War appointed a Board of Engineers, composed of Capts. A. A. Humphreys, G. G. Meade, and William B. Franklin, Corps of Topographical Engineers, to examine and report upon the Rock Island bridge. Their report is dated May 9, 1859, the examination having been made in April preceding. This Board considered the engineering questions, and made careful measurements of velocities, and determined the injurious effect of the piers. They reported that the bridge was not only a material obstruction, but one materially greater than was necessary. The report was printed with the report of Col. J. J. Abert, Chief of Topographical Engineers, annual report of the Secretary of War for 1859, pp. 836, 837, 838, 839, 840, 841. It was the cause of the provision in the bridge laws requiring the piers to be parallel to the current. I have, on account of its general bearing on the subject of bridging the Mississippi, inserted it here:

DETROIT, MICH., *May* 9, 1859.

SIR: The Board of Engineers organized in conformity to your letter to the honorable Secretary of War, dated March 1, 1859, for the purpose of making certain examinations upon the construction of the railroad bridge across the Mississippi River between Rock Island, in the State of Illinois, and Davenport, in the State of Iowa, has the honor to submit the following report:

The Board was furnished with copies of the letter addressed to the honorable Secretary of War by certain Senators and Representatives in Congress asking for its appointment, and the letter of the Bureau of Topographical Engineers to the War Department specifying points for the Board to examine and report upon. Copies of the maps of the survey of Rock Island Rapids, made by Capt. R. E. Lee, Corps of Engineers, in 1837, and of the survey of the same rapids, made by Lieut. G. K. Warren, Corps of Topographical Engineers, in 1853, were also furnished.

It being understood that the condition of the bridge was a subject of greater complaint at high than at low stages of water, the Board awaited the intimation of Mr. J. W. Bissell, agent of the Saint Louis Chamber of Commerce, that the river was in a favorable condition for examination, upon the receipt of which information it proceeded to Davenport, Iowa, arriving there on the 22d of April last. At Davenport the Board found Mr. Bissell, with assistants, instruments, &c. It also met the president, superintendent, and other officers of the railroad companies interested in the bridge, from whom it received detailed drawings of the bridge in all its parts, with surveys of the river and other valuable information, saving much time in the examination.

The Board takes this occasion to express its thanks to all of the above-mentioned gentlemen for the courtesy extended to it during its visit.

As the Board was advised of the fact that the expenses were to be borne by the Saint Louis Chamber of Commerce, and found Mr. Bissell prepared with the necessary means, it proceeded at once to make the observations requisite to enable it correctly to report upon the various points submitted to it in its instructions.

From the drawings above alluded to, and from personal examination, the Board found that the railroad bridge is placed at the foot of the rapids, and is thrown from the island of Rock Island to the city of Davenport, Iowa; that it is supported by two stone abutments on the shores and six stone piers. The spans (five in number) are 250 feet broad, the draw-spans being at the water level (9½ feet stage) 117 and 112 feet, respectively, making the whole length of the bridge 1,535 feet.

The piers, except those of the draws, are 35 feet long and 7 feet broad at top, and 53 feet long and 11 feet broad at the bottom. The two small draw-piers are 38 feet long and 10 feet broad at top, and 54 feet long and 14 broad at the bottom. The turn-table pier, including the guard-pier and starling, is 355 feet long and 40½ feet broad at the top, and 386 feet long and 45 feet broad at the bottom.

This pier is composed of a stone center pier 35 feet in diameter at the top, the remainder being crib-work filled up with stone. The upstream starlings of all the piers are isosceles, right-angled triangles. The center line of the roadway crosses the turn-table pier 210 feet from its head; this pier being 115 feet longer and 19 feet wider on top than the truss which forms the draw. The superstructure of wood, built upon Howe's patent, is 20 feet above ordinary high and 33 feet above ordinary low water.

The first points to which the Board directed its examinations were the velocities and directions of the currents. To determine these with accuracy, bases were measured above and below the bridge, and observers, with theodolites, were stationed at each extremity of these bases. Floats of different depths, ranging from 1 to 8 feet, were started in all parts of the stream, and simultaneous angles were taken to them at given intervals, by which means the exact path of the float and velocity were determined with accuracy. Additional observations were made with Masi's patent log, care being taken to compare a sufficient number of velocities obtained from these with those determined by the floats, to get the correction which these instruments require. The results of these observations are shown graphically on the map submitted with this report, and are also tabulated and annexed in the Appendix C.

By examining the map and table, it will be seen that the current in the main channel, at a point 1,200 feet above the bridge, and beyond its influence, is 4.3 miles per hour; that under the bridge it varies from 4.5 to 6.4 miles per hour; and that at a point 1,700 feet below the bridge, where the river has resumed its regimen, the current is 3.75 miles per hour; and, finally, that at a point one mile below the bridge it is only 2.8 miles per hour.

It will be seen that above the bridge the direction of the current makes with the axis of the piers different angles, varying from 26° to 14° 40′; that, through the Illinois draw of the bridge, the angle with the axis of the pier is 5°, and that below the bridge the angle varies from 8° to 9° 30′.

After obtaining the directions and velocities of the currents, the differences of the level of the water in and about the Illinois draw were determined. These levels are shown in the annexed sketch (Appendix D). An inspection of these levels will show that the fall of the water from the head to the foot of the turn-table pier is 16 inches. Other differences of level are also given. The Board, with the data furnished by the company, viz, the cross-section of the river under the bridge, and the detailed dimensions of the piers, has computed the obstructions to the flow of the water due to the submerged part of the bridge. The obstruction due to each pier was computed as follows: The cross-section of the submerged part of the pier, perpendicular to its length, was computed from the data furnished by the railroad company. This area was multiplied by the cosine of the angle of inclination of the current to the axis of the pier. The product was the obstruction due to the width of the pier.

The area of the submerged side of the pier was multiplied by the sine of the angle of inclination of the current to the axis of the pier. The product was the obstruction due to the length of the pier. This product added to the first gave the total obstruction due to the pier. The starlings have been left out of consideration in the calculation, and only the lengths of the straight part of each pier has been taken. The results of these computations are attached to this report (Appendix E).

An inspection of this table shows that the total obstruction presented to the flow of the water is 4,881 square feet, and that the portion of this amount due to the inclination of the current is 3,216.2 square feet, or .66 of the whole; that is, were the same piers placed parallel to the current, the obstruction to the flow of the water would be about one-third of what it now is.

The Board also computed the height of backwater due to this obstruction, and the increase of velocity imparted to the current thereby. The data for this computation were the elements of the cross-section and piers as furnished by the railroad company and the assumed mean velocity at the site of the bridge, prior to its construction, 4 miles per hour. This last quantity was deduced in the absence of actual observation by finding it to be the mean velocity above the bridge and beyond its influence at a point where the area of the cross-section was the same as that of the site of the bridge. The computations and their results are given in the Appendix F.

The general level of the river is raised by the piers of the bridge .49 foot, or nearly 6 inches, and the increase of the mean velocity due to the contraction of the water-way is 2.27 feet per second, or 1.55 miles per hour, making the computed velocity under the bridge 5.55 miles per hour.

The Board finally examined the river below Rock Island, and carried a line of soundings across the river on the line of the ferry between the cities of Rock Island and Davenport. The maximum depth in the channel-way was found, near the Iowa shore, to be about 22 feet, and the velocity of the current 2.8 miles per hour. The bottom in the channel-way was rock, and in other parts coarse gravel and sand.

The Board has now presented all of the facts collected by it, and proceeds to report *seriatim* upon the points referred to in the letter of the Bureau of Topographical Engineers, dated March 1, 1859, a copy of which is hereto appended. (Appendix B.)

1. The Board is of the opinion that the railroad bridge which crosses the Mississippi River between Rock Island, in the State of Illinois, and Davenport, in the State of Iowa, is not constructed according to correct principles, reference being had to the interests of navigation.

2. The piers of the said bridge are not of the best form, and that there was no practical difficulty in constructing them of the proper form. With the exception of the turn-table pier, the Board is of the opinion that the defective form of the piers is a matter of no material importance. The turn-table pier will be more particularly referred to in the answer to the next question.

3. The only pier larger than is necessary is the turn-table pier. This pier, in the opinion of the Board, should have been constructed no longer or broader than was absolutely necessary to sustain the truss when the draw is open and protect it from injury by passing boats. It might have been constructed with a length of 295 feet, affording ample support and protection, and being actually 355 feet in length; the difference, 60 feet, is unnecessary, and, in the judgment of the Board, pernicious. The effect of making it longer than was absolutely required is to contract the water-way, increase the velocity, narrow the draw-passage, and present more surface for boats to strike against, thus increasing the difficulty of their passage through the draw. In a pier of this size, the form of the starling is of importance, and the upper faces of the pier should have been curved surfaces.

4. The piers are not placed parallel to the current, but at angles varying from 26° to 14° 30′. The effect of this obliquity is to treble the obstruction to the flow of the water, and consequently to affect the increase of velocity in the same ratio. Another consequence is that the passages of steamboats and rafts through the draw and between the piers are rendered much more difficult and hazardous. Furthermore, the draw on the Iowa side is rendered useless by the formation of an eddy therein.

5. The velocities of the different parts of the river in the vicinity of the bridge have already been stated, and will be found tabulated in Appendix C.

6. The eddy on the Iowa side of the turn-table pier, as nearly as could be estimated,

is about 100 feet at the foot of the pier, and the turbulence or boiling of the water extends about 500 feet below. This eddy, however, is constantly varying in its position and dimensions. Its effect on the passages of boats ascending and descending is undoubtedly to render them more difficult, on account of the care required to avoid getting one part of the boat in it while another part is in the current of the draw. It has been previously stated that the effect of this eddy in the Iowa draw is to render it useless.

7. The surface of the water at the upstream end of the turn-table pier is 16½ inches above the surface of the water at the downstream end. The extent of the backwater or *remous*, as nearly as could be estimated, is about 150 feet.

8. The bridge is badly located, and, in consequence of this bad location, is a greater obstruction to the passage of steamboats and rafts than would have been necessary had the location been good. Any site in the vicinity below Rock Island, out of the rapid current, would have been better. The Board, having this fact in view, examined the line of the ferry between Rock Island City and Davenport, and found that there would be no practical difficulty in the erection of a bridge at this site or near it, which bridge, if constructed on proper principles, would be no material obstruction to navigation.

9. The Board, under this head, deems it expedient to submit a statement of the number of steamboats and rafts which have passed the bridge, as well as the number of passengers and loaded cars that have crossed it since its opening. These statistics, obtained from the records and reports of the railroad company, are submitted to show the magnitude of the interests involved in the commerce that passes over and under the bridge (Appendix G). The Board passed the bridge in steamboats, ascending and descending, and also witnessed the passage of numerous boats and rafts.

The question of the practical difficulty of passing the bridge being dependent on the size and power of the boat, the draught of water, shape of hull, and obedience to helm, shape of the upper works, and direction and force of the wind, together with the personal skill and judgment with which the boat is managed—conditions varying with each boat, and requiring special knowledge—the Board has not thought it incumbent upon it to enter into its discussion, particularly as it is well known that this matter is now before the courts, and that the testimony of experts is being taken.

The Board, too, has considered that the duty imposed upon it is one purely of engineering.

In this view of the case it has endeavored to collect all of the facts and data for the correct solution of the problem, with an earnest desire to bring into the discussion only material points, and in its deductions to do justice to all parties concerned.

In conclusion, the Board considers it proper to recapitulate some of the well-known principles of bridge-building, to show how far they have been conformed to or departed from in the Rock Island bridge. These principles are:

First. That at a given place, in locating a bridge over any stream, the site where the velocity of the current is a minimum should be selected.

Second. That in designing a bridge the piers should have a minimum cross-section consistent with the support of the superstructure, thus offering the least obstruction to the flow of the water, and increasing the velocity of the current as little as possible.

Third. The piers should alway be placed parallel to the thread of the stream for the same reasons as those stated in the second principle, and because they thus render the passage of boats and rafts less difficult.

Fourth. In designing a bridge over a river having a large commerce in boats and rafts, the draws and spans should be of the greatest practicable width.

In applying these principles to the Rock Island bridge the Board is constrained, with extreme regret, to report that all have been violated, thus rendering the bridge not only an obstruction to the navigation of the river, but one materially greater than there was any occasion for.

The Board fully appreciates the value and importance of the railroad traffic, and is of opinion that a bridge is necessary, and should be constructed, not only at Rock Island, but at other points on the Mississippi River; but it is also of opinion that the interests involved in the free navigation of this noble stream demand that in locating and constructing these bridges unusual study should be brought to bear to insure the presentation of the least possible obstruction to the navigation, and that all considerations of expediency and economy should be made to yield to the paramount interests of the commerce of the river.

Very respectfully, your obedient servants,

A. A. HUMPHREYS,
Captain Corps Topographical Engineers.
GEO. G. MEADE,
Captain Topographical Engineers.
WM. B. FRANKLIN,
Captain United States Topographical Engineers.

Col. J. J. ABERT,
Corps Topographical Engineers, Washington, D. C.

There was no longer a doubt that this bridge was a most serious and dangerous obstruction to navigation, owing to its bad location and faulty construction.

A final hearing of the case of Ward *vs.* The Mississippi and Missouri Railroad Company was had before Judge Love, at the March term of 1860, at Keokuk, Iowa. The testimony of the members of the Board of United States Engineers was taken at this hearing. The court, on the 3d of April, ordered, adjudged, and decreed as follows:

> That that portion of the railroad bridge across the Mississippi River at or near Davenport, within the State of Iowa, being a part of the commonly called Rock Island Bridge, and which is a part of the Mississippi and Missouri Railroad, is a common and public nuisance and a material obstruction to the navigation of the said river by steamboats and other craft; that so much thereof as is within the State of Iowa, to wit, all the piers between the long or turn-table pier and the Iowa side, was at the time of filing the said bill and has ever since been the property of the defendant, and in the possession and under control of the defendant. That the complainant was, at the time of filing his bill, and for a long time prior thereto had been, a boat-owner and navigator of the Mississippi River by steam and a commander of steamboats in the trade from Saint Louis, Mo., to Saint Paul, Minn., and so continued to the time of this decree; that he was at the time of filing his bill the owner of the interest in the steamers *Connewoga*, *Pembina*, and *Canada*, set out in the amendment to his bill, and that they were of the value therein stated, and was the commander of the *Canada*, and continued such owner and commander to the time of this decree: that he was, at the time of filing his bill, engaged with said boats in the same trade, carrying freight and passengers, and so continued during the time aforesaid; that said boats were during all that time duly fitted up, manned, equipped, inspected, licensed, and enrolled under the laws of the United States relating to vessels propelled in whole or in part by steam, and carrying freight and passengers, and to those relating to the coasting trade and fisheries, and were being used by the complainant in carrying on commerce in said trade under said laws as common carriers of passengers and merchandise; that as such owner, commander, navigator, and common carrier, the complainant, at the time of filing his bill, had, and continued to have, a special and peculiar interest in the navigation of said river between the points aforesaid, and in its commerce between the same, and at the place where said bridge is located; that said bridge is a material and serious damage, hinderance, and obstruction to him in his said business as a navigator and owner of steamboats engaged in said commerce, and that he suffered large and irreparable injury therefrom at the time he filed his bill, and continued so to suffer such injury, and for which there was and is no adequate remedy at law, and that he is entitled to have said bridge abated and removed and the river restored to its original condition.
>
> And the court does further order, adjudge, and decree that the defendant abate and remove all of the said piers within the State of Iowa, together with the superstructure thereon, on or before the first day of October next; that said defendant commence said abatement and removal within thirty days from the entry of this decree, and proceed therewith as rapidly as it may reasonably be done; and that they remove the pier next to the long pier on or before the first day of July next, and the remainder of it by the first day of October next.
>
> It is further ordered, adjudged, and decreed that in default of said abatement and removal as aforesaid, that an order issue to the marshal of the district requiring him to abate and remove the same as is hereinbefore provided, and that he summon to his aid all necessary and proper assistance therefor.
>
> It is further ordered, adjudged, and decreed that the said removal be made at the costs of the defendant, and said defendant pay all costs which have now accrued, taxed at $, within ninety days from entry of this decree, and any and all further costs in executing this decree from time to time as they accrue, and within forty days from the time of their taxation, and in default of the payment of the costs aforesaid that execution issue therefor.

On the 4th day of April the solicitor for the railroad company prayed an appeal to the Supreme Court of the United States from the decree of the district court, which appeal was allowed on the filing of a bond for the sum of $10,000.

The decision in this appeal by the Supreme Court was that the court in the district of Iowa had no jurisdiction to remove the part of the bridge which was within the State of Iowa. There were three dissenting judges, but neither they nor the majority touched the question as to whether the bridge was or was not a material obstruction to navigation· This case, Ward *vs.* The Mississippi and Missouri Railroad Company, is reported in 2 Black's Supreme Court Reports, p. 485.

There was no longer a question that some further action on the part of Congress was necessary to give to the courts the requisite jurisdiction to try suits against the bridge company. The troubles preceding the war which broke out in 1861 probably absorbed too much of the attention of Congress to allow of any further consideration of the case at that time or at any time until the war was over. Then it was decided to establish an arsenal on Rock Island, and to have the railroad track removed to such part as would not interfere with the use of the island for the purposes of an arsenal, and to build a new bridge adapted to the uses of a highway as well as a railway. The first act for removing this bridge was approved June 28, 1866; it made the same requirements in the interests of navigation as the act authorizing the bridge at Quincy, Ill., passed at the same session. In 1872, the new bridge being finished, the first bridge was taken down.

This bridge is described in the report of the Board of Engineers inserted above. It is shown on the map of the new bridge (Diagram 20) accompanying this report, Chapter IV, with very numerous observations upon the currents as they were about the piers.

In the debates upon the bill for the removal of this bridge but little was said concerning the bad features of it, but they were frequently referred to in the debates upon the bill authorizing a bridge at Quincy, Ill., and in the debates upon the bill declaring the bridge at Clinton a post-route, abstracts of which debates are given further on.

The following is an abstract of the debates upon the act of 1866, which provided for the removal of this bridge:

In the Senate, on May 21, 1866 (Debates, page 2706), Mr. WILSON, chairman of Committee on Military Affairs, reported Senate bill No. 330, to provide for occupying Rock Island as an arsenal. On May 22 (p. 2738) Mr. WILSON explained objects of the bill. It proposes to direct the Secretary of War to fix and establish the position of Chicago and Rock Island Railroad on the island of Rock Island so as to best accord with the purposes of the government in its occupany of that island for military purposes.

The bill passed.

In the House of Representatives on May 23, 1866 (p. 2780), Senate bill No. 330, Rock Island arsenal, &c., received.

On May 26 (p. 2839), referred to Committee on Military Affairs.

On June 22 (p. 3351), Mr. SCHENCK, chairman of Committee on Military Affairs, reported Senate bill No. 330, with an amendment as a substitute. It extended the provisions in regard to the bridge, and made them more definite and positive.

The bill was explained and passed.

On June 22 (p. 3337), Senate bill No. 330, bridge at Rock Island, &c., returned from the House to the Senate.

On June 22 (p. 3349), Mr. WILSON said:

> The amendment is a substitute which I recommend.

This was agreed to.

In the House of Representatives, on June 23 (p. 3375), message received from the Senate that the substitute was adopted and passed.

Both the cases of the bridges at Wheeling and at Rock Island illustrate the great delays attending all attempts at redress in suits in equity, and the necessity for Congressional legislation to regulate the building of bridges so as not to unnecessarily obstruct navigation.

ABSTRACT OF DEBATES IN CONGRESS PRECEDING AND ATTENDING THE LEGALIZING OF BRIDGES ACROSS THE MISSISSIPPI RIVER.

In completing the history of the first Rock Island bridge above, I have been carried beyond the time of the authorization and building of the important railway-bridge across the Ohio River at Steubenville; but, as I shall have occasion to particularly refer to it further on, when speaking of my official duties connected with it, I have thought best to continue the account of the Mississippi River bridges. The following abstracts of the Congressional debates are not only interesting as a part of the history of the subject of bridging, but show the points raised and directions in which I was expected to pursue the investigations which Congress then authorized:

The subject was introduced in the House of Representatives on December 20, 1865 (Debates, p. 70), by Mr. **Harding**, of Illinois, by a joint resolution to declare a certain bridge and ferry across the Mississippi River at Quincy, Ill., a post-route and national highway of commerce. It was referred to the Committee on Roads and Canals.

On February 19, 1866 (p. 919), Mr. **Wilson**, of Iowa, introduced into the House of Representatives a bill to authorize a bridge at Keokuk, Iowa, for a railroad and wagon-road, and declare it a military and post-road, which was referred to the Committee on Post-Offices and Post-Roads.

In the Senate, on February 23, 1866 (p. 979), Mr. **Howe**, of Wisconsin, introduced Senate bill No. 163, authorizing Milwaukee and Prairie du Chien Railway to bridge the Mississippi River, which was referred to the Committee on Post-Offices and Post-Roads.

On March 7, 1866 (p. 1333), Mr. **Paine**, of Wisconsin, offered in the House a bill to authorize a bridge at Prairie du Chien, Wis., and declare it a post-route, which was referred to the Committee on Post-Offices and Post-Roads.

On March 8, 1866 (p. 1252), in the Senate, Mr. **Ramsey**, chairman of the Committee on Post-Offices and Post-Roads, reported Senate bill No. 163 with amendments.

On March 27 Mr. **Trumbull** introduced Senate bill No. 236, to establish certain post-roads (a bridge and ferry across the Mississippi River at Quincy, Ill.), which was referred to the Committee on Post-Offices and Post-Roads.

On April 12 (p. 1906) Mr. **Norton** introduced Senate bill No. 263, authorizing the Winona and Saint Peter's Railroad to construct a bridge as a post-route, which was referred to the Committee on Post-Offices and Post-Roads.

On April 16 (p. 1954) Mr. **Ramsey** introduced a joint resolution to appoint a commission of Army Engineers to examine and report upon construction of railroad bridges across the Mississippi River.

On April 19 (p. 2033) Mr. **Ramsey** reported Senate bill No. 236 with amendments.

On April 25 (2163) Mr. **Ramsey**, in explanation of Senate bill No. 236, said, it makes it lawful for any one having authority from the State of Illinois to build a bridge at Quincy, Ill., to be a pivot draw-bridge, the openings each side of this pivot to be not less than 150 feet, placed at an accessible and navigable point, and of the next adjoining spans not less than 250 feet; there must be a span over the main channel of the river not less than 300 feet in length; the bottom chord to be not less than 30 feet above low-water, nor less than 10 feet above high-water; to be recognized and known as a post-route. He amended (1st) to require the authority of Missouri as well as Illinois, which was agreed to; (2d) to provide for litigation, by extending the jurisdiction of the United States district courts over the bridge in any State in which any portion of the bridge touches; this was agreed to; (3d) to strike out the provisions for length of span, and, instead, leave it optional to make it with a draw or with continuous spans. In the latter choice, elevation of bottom chord must not be less than 50 feet above extreme high-water and the spans not less than 250 feet, with piers parallel with the current; if a draw-bridge with a pivot, the draw must be over the main channel at an accessible point, and with spans of not less than 175 feet in length on each side of the pivot pier, and the next adjoining spans not less than 250 feet; the bottom chords not to be less than 10 feet above high-water nor less than 30 feet above low-water; amendment agreed to.

Mr. HENDERSON, of Missouri, desired to amend by adding Hannibal, Mo., after Quincy, Ill.

Mr. RAMSEY objected, and suggested its withdrawal, and that it be offered as a separate bill.

Mr. HENDERSON pressed his motion and stated his reasons. He thought it an act of justice to Hannibal, which had every claim to the privilege that Quincy had. He lived within 30 miles of both places. He was opposed to all low draw-bridges, and would vote against the bill even if his own amendment was adopted. The bridges built under these provisions would surely be draw-bridges, not high continuous spans. He claimed that they should be high bridges, as provided in the bill for Saint Louis, with bottom chords 50 feet above extreme high-water, but instead of spans 600 feet, he would accept 400 feet.

A Senator said, "It cannot be done."

Mr. HENDERSON said, "Mechanics say it can be done; they inform me that a span of 600 feet can be built."

Another Senator said, "Only by iron suspension."

Mr. HENDERSON answered, "I care not how it may be done. We want high and wide spans. In the course of a few years transportation by barges alongside of steamboats has come into practice, requiring much more space than formerly. Rafts are sometimes 300, 400, and 500 feet in length. It may be said that rafts are never as wide as 150 feet; that I do not know, but some are very wide, and repeated difficulty has been experienced in getting them through the Rock Island bridge. A raft may enter the opening properly, but before the entire raft gets through it may strike the piers."

Mr. GRIMES said, "The bridge at Rock Island is right at the foot of the rapids, where the current is very strong; but no such condition can exist at Quincy."

Mr. TRUMBULL said, "The span there is only 112 feet."

Mr. RAMSEY said, "The whole difficulty at Rock Island is the obliquity of the piers to the current."

Mr. HENDERSON said, "That is the very difficulty that I am suggesting."

Mr. RAMSEY said, "That is well guarded against in this bill. They are here required to be in the line of the current."

Mr. HENDERSON said, "But it may be that they are in the line of the current in low-water, and yet will not be in the line of the current at high-water. The current of the Mississippi is not always in the same line; the current changes even in high and in low water."

On April 26 (p. 2192) Mr. NORTON moved that Senate bill No. 263 be printed. Ordered.

On April 30 (p. 2266) Mr. HENDERSON withdrew his amendment for the present.

Mr. GRIMES offered an amendment to authorize bridge at Burlington, Iowa.

Mr. RAMSEY spoke at length on the general subject. He described the three bridges built at Saint Paul, Clinton, and Rock Island: the first high and no obstruction, the others alleged to be very obstructive. He quoted from the report of Board of United States Engineers, condemnatory of the Rock Island bridge, and explained the action of his committee. The provision for continuous spans with bottom chord 50 feet above high-water, he said, experienced river-men told the committee was all that is desired.

> Where the chimeys are taller than that, the arrangement is to lower them upon the telescopic plan, which has been introduced there.

With regard to the spans, other than the pivot span, we have the information of competent engineers that an excess of 300 feet is not advisable. General McCallum, civil engineer, who had charge of railroad and bridge structures during the war, says:

> The longest draw-bridge ever constructed in this country is of two openings of 150 feet each. Although I do not consider even a greater width impracticable, I nevertheless would consider it unnecessary and impolitic. Any bridge located at right angles with the stream, with current of not more than 4 miles an hour, all purposes of navigation should be fully met by 150 foot openings.

Mr. HOWE said, "I understand the bill provides for these openings to be 175 feet."

Mr. RAMSEY, "No; the pivot-pier and the one-half of the rest-pier at each end on which it rests detract from their width. The length of the whole span is 350 feet and leaves a clear draw of 150 feet. That much can be done, and I think it ought to be conceded. I think in this bill we have guarded all these various interests on the river. We have insured a passage-way sufficiently large, the piers to be in line with the current; to be 50 feet above high-water, if with continuous spans." He said, "I would oppose bridging in the interest of my State and of navigation if we could avoid having bridges, knowing that the river trade of 1865 amounted to twice as much as our foreign commerce; but, from the immense capital invested in the railroads that approach the river, they will cross it. It cannot be expected that they can be successfully resisted forever. The fact is, that almost in spite of law they are building bridges. It is, then, important at this time, before these structures are up, when it will be impossible to remove them—the interest retaining them being so large—that Congress should step in and regulate the construction so as to be as little injurious to navigation as possible."

Mr. HOWE asked what evidence there is that a draw of the length prescribed is manageable.

Mr. RAMSEY said, "There is an iron swing-bridge at Brest, France, spanning a water passage of 347 feet in the clear, which cost $406,000. It is a government work. It is desirable we should strike a medium in the erection of these swing-bridges across the Mississippi, so as to neither injure the river nor the bridge interest. If we make them too large, they will often be out of order and immovable and the boats cannot pass. If they are made of smallest size, as requested by some, the channel-way will not be large enough for business. They should be easily workable, and at the same time as large as can be allowed. This is the proper medium."

Mr. GRIMES stated he would support the bill, and said that the draw at Rock Island was only 112 feet.

Mr. **Ramsey** said, "One is 112 feet, the other 117 feet."

Mr. **Grimes** said, "This bill requires the draw to be 175 feet."

Mr. **Ramsey** said, "Not 175 feet, but 150 feet; probably a few feet more."

Mr. **Trumbull** said, "That had better be more definite, so as to make its meaning clear."

Mr. **Grimes** said the bridge company could always locate the draw so as to have the current at all stages directly through it. He knew the currents changed, but experience had shown that works could be built to preserve them in a desired course.

Mr. **Ramsey** said, "I have the opinion of Captain Blakely, who has a long experience in navigating the Mississippi River, to the effect that the draw-openings should not be less than 150 feet in the clear, and, if practicable, 175 feet in the clear. Capt. W. F. Davidson, a long and successful navigator, says he thinks the bill should be amended so as 'to force the company to build a draw,' considering that less obstruction than the bridge with continuous spans."*

The committee did not feel at liberty to report against allowing these bridges, and, in many respects, thought it desirable to seize this opportunity of regulating them. Mr. **Ramsey** said he would, however, at the same time, desire that Congress should authorize the President or Secretary of War to send a commission to survey the whole river, and decide, at least as to the future, what should be the character of the bridges there. "The probability is that, before theclose of the next session of Congress, you will be compelled to authorize a dozen of these bridges. The thing will get to be serious when they come to be so numerous as that. I think we have guarded this bill as well with the light before us as it was possible to do, and yet I should like, when this extensive building of bridges on the Mississippi River is entered upon, to have the opinion of a board of scientific engineers; and, with that view, some days since I introduced a joint resolution, which was referred to the Committee on Commerce, but they have not seen fit to return it with a report. I feel reluctant to vote for any other bridge than the one reported by the Post-Office Committee on this bill, simply because it is but one, though I have no particular objection to any other, except as to the number; but I hope when this bill passes we shall authorize a commission to be sent to survey the river and determine and settle the essential points to be guarded in the construction of these bridges, how, when at the same time the railroads may be accommodated, the navigation shall be protected. My resolution was in the following language:

> "That the Secretary of War be directed to appoint a commission, to consist of three officers of the Corps of Engineers of the Army, to examine and report at the present session of Congress, if practicable, and, if not, before the next session of Congress, upon the subject of the construction of railroad bridges across the Mississippi River, at such localities and upon such plans of construction as will offer the least impediment to the navigation of the river; and that $10,000, or as much thereof as may be necessary, be hereby appropriated.

"I should much prefer, before very many bridges are authorized, that this commission should be sent out to view the river, and furnish us the best information on the subject."

Mr. **Henderson** offered an amendment making an additional section to the bill, and authorizing a bridge at Hannibal, Mo. It was agreed to.

Mr. **Henderson** next proposed to amend the second section by striking out that part which left the bridge-tender to decide whether the boat could go under or not after receiving the signal for opening the draw. He thought there might be a troublesome question raised here between the bridge-men and the boatmen. This amendment was rejected.

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* Since the building of the draw-bridges Captain Davidson has retracted this opinion.—G. K. W.

Mr. **Henderson** moved to amend by striking out the fourth section, declaring the ferry at Quincy a post-route.

Mr. **Grimes** sustained the amendment.

Mr. **Trumbull** opposed it, but said he had no interest in it further than to authorize these great lines of travel to accommodate themselves to each other. He thought the time had come when we have got to have bridges.

The amendment was agreed to.

Mr. **Henderson** wished to further amend by compelling the bridge to be of continuous spans. He said that all the interests he represented wanted high, continuous spans. He said when the law authorizing the bridge at Steubenville was passed, Senator Collamer, who reported it, requiring spans of 300 feet, said he did not believe it possible, yet it was built, the bridge costing $900,000. The Senate being in Committee of the Whole, and this an amendment to an amendment already agreed upon, was decided to be out of order; the bill was then reported to the Senate.

Mr. **Trumbull** moved to make the bill so read that the draw-openings should be 150 feet in the clear, which he understood to be the intention.

Mr. **Ramsey** said that, as worded, the widths of the pivot and adjoining piers might be such as to leave a little more than 150 feet in the clear, and inasmuch as he would like to have 200 feet in the clear he wished to hold on to all the bill allowed as reported from the committee.

Mr. **Henderson** opposed Mr. Trumbull's motion. The bill was clearly drawn with the idea that the openings should be 175 feet in the clear.

Mr. **Ramsey** said they were not expected to be that in the clear.

Mr. **Henderson** urged to have wider draws. He said, "They have wider ones in France; why cannot we have them here? Is it possible to build a bridge with a draw 175 feet? If so, there is no stream on God's earth that requires this width of draw more than the Mississippi. I warn the gentlemen, who are just as much interested in this subject as I am, that they are doing a thing this morning they will regret in the future. They should remember that they are interfering with that navigation which is much better for the people than any transportation they can get by rail."

Mr. **Grimes** said that the river takes the transportation in the wrong direction. "We are not only anxious sometimes to go to Saint Louis, but for facilities for reaching the eastern cities. We want, if possible, to be able to do so in the winter, when the ice is running, when it is impossible to cross sometimes for weeks in succession without great risk of life; and we want the opportunity, when we choose, to send our freight and live-stock to the only market we have, without breaking bulk at the Mississippi River. This bridge is opposed, because it does not give sufficient opportunity for boats to pass. Did not the three Army engineers state that the objections to the Rock Island bridge were solely because the piers were not parallel with the stream? Is not this bill prepared to meet that objection? I, who live on the Mississippi, and represent several tolerably important towns, am deeply interested in the navigation of the river, and I would not do a single thing here or elsewhere that could by any possibility obstruct the free navigation of the stream; but we want at the same time, if it can be done, and we are satisfied that it can be done, opportunities to get eastward as well as southward and northward."

Mr. HENDERSON said he considered the bill to mean clear openings of 175 feet, else why did the chairman of the committee read a letter from a steamboat captain saying such a width was required?

Mr. TRUMBULL said the chairman had twice stated he did mean that, and it is best to have the wording so that there shall be no doubt about the meaning. I have consulted the Senator from Minnesota (Mr. Ramsey), and he is willing to make it specific, by saying the openings shall not be less than 155 feet.

Mr. RAMSEY said, "I agree to that."

Mr. HENDERSON said, "I will compromise with the Senator from Illinois, if he will put it at 160 feet."

Mr. TRUMBULL said, "Well, I will agree to that."

Mr. HENDERSON said, "Very well."

The amendment was agreed to.

Mr. HENDERSON proposed to amend by inserting the requirement that, if with continuous spans, the main span should be over the main channel and not less than 300 feet wide.

Mr. RAMSEY said, "I do not insist that the spans shall be only 250 feet. I have the opinion of an engineer attached to the War Department. He says:

> "In regard to the question of economy and practicability of truss-bridges for railroads, I have the honor to state that, in my judgment, spans of 250 feet in the clear are as great as should be adopted for crossing navigable rivers.

"These are the extent of the spans we are familiar with. The great bridge constructing across the Susquehanna River has spans of 250 feet. It is desirable to have 300 feet, if the Senate think they can be constructed of that width."

Mr. HENDERSON said, "Every bridge on the Ohio is built with 300-feet spans. It is a general law (pp. 289–290 of the Senate acts of 1861–'62). Several bridges have been built not under the law, and they have led to continual controversies in the courts."

Mr. RAMSEY said that "in a narrow stream a high bridge is easier thrown, but the Mississippi is wider than the Ohio."

Mr. HENDERSON said, "But that has nothing to do with the span."

Mr. RAMSEY said he had no objection to the amendment.

Mr. HENDERSON said, "I wish also to provide that, if a bridge with continuous spans, the span next the main span shall not be less than 220 feet, and no space over the part where water flows at low-water shall be less than 175 feet."

Mr. RAMSEY said, "But you are shortening the length of spans from 250 feet to 220 feet."

Mr. HENDERSON said, "There certainly can be no objection to that."

Mr. RAMSEY said, "I do not object to enlarging the main span to 300 feet, but I do to reducing the other spans from 250 feet to 220 feet."

Mr. HENDERSON asked if there is any objection to the 300-feet span.

Mr. KIRKWOOD said, "That is assented to, I understand."

Mr. HENDERSON said, "I suppose that is not a matter of very great consequence, because all these bridges will now be built with a pivot-pier."

He then proposed an amendment to include all the provisions he had presented.

The amendment was rejected—yeas, 7; nays, 21; absent, 21. There was apparently a misunderstanding, for right after this vote the amendment to have the main span 300 feet and over the main channel was adopted.

The Senate then concurred in the amendment as amended, and also adopted the additional section providing for a bridge at Hannibal.

Senate bill No. 236 was then passed.

On April 30 (p. 2299), Senate bill No. 236, to authorize certain bridges and to establish post-routes, was received in the House.

On May 1 (p. 2303), Mr. RAMSEY reported, in the Senate, Senate bill No. 263, with amendments.

On May 2, in the House, Mr. HARDING, of Illinois, moved that Senate bill No. 236 be printed; it was ordered. On May 3, Senate bill No. 236 was amended so as to authorize any railroad to build bridges on same terms; also specifying the bridge at Keokuk. The matter was debated, and the bill, as amended, referred to the Committee on Post-Offices and Post-Roads.

On May 14 (p. 2562), Senate bill No. 263 was taken up in the Senate, and Mr. RAMSEY, chairman, said it had been considered by the Committee on Post-Offices and Post-Roads, who had the other bills in charge, and, as amended, it is similar to the one we passed a few days since. The amendments were agreed to.

On May 18 (p. 2665), Mr. HOWE said, "I desire to call attention to the amendment of the first section. Is not that a new principle? It is as follows:

> "And in case of any litigation arising from any obstruction or alleged obstruction to the free navigation of said river, the cause may be tried before the district courts of the United States of any State to which any portion of said obstruction or bridge touches."

Mr. RAMSEY (p. 2665) said, "It is embraced in all the other bills that have been reported here by the Post-Office Committee. It is to avoid a difficulty that occurred in the litigation in regard to the Rock Island bridge. I believe the proceedings were first had in the district court of Iowa; and I think it was then held they had jurisdiction only to the thread of the stream, and hence had not jurisdiction of the whole matter of the bridge. This is to give that jurisdiction to the courts."

Mr. HOWE said, "I have no objection to it."

Mr. RAMSEY said, "The amendment was suggested by those who have in charge the interests of navigation at Saint Louis."

Mr. HOWE proposed to amend the bill so as to allow the bridge to be built either at La Crosse or Winona, as the legislatures of the two States should elect.

Mr. NORTON opposed this because there was no railroad or authority to build one from Winona to La Crosse, and that the Wisconsin legislature would give it to La Crosse and the Minnesota legislature to Winona, and there would be no bridge at either place.

The debate continued on this amendment until the consideration of the bill was postponed.

On May 22 (p. 2760), Mr. HOWE'S amendment was further discussed and rejected.

Mr. HENDERSON offered an amendment to strike out the provision for a draw-bridge, and require continuous spans. He said: "High bridges of 400-feet spans of truss are practicable. It was strenuously urged the other day, when a similar proposition was before the Senate, that one bank of the Mississippi is always low, and that, therefore, it will be impossible to build these high bridges. It seems to me better to intrust the matter to a board of scientific men—a board of engineers. The Senator from Minnesota (Mr. Ramsey) has proposed a resolution that I think this body ought to adopt before going into this business of bridging with low draw-bridges the Mississippi River. He proposes to have a scientific board established to go out and examine the Mississippi River and see at what points it may be safely bridged, and report the character of the bridges that, under the circumstances, ought to be constructed. Let them go out and report to this body at the next session whether this thing is practicable or not; they can report by next December. Draw-bridges are an immense obstruction. I have been told by steamboatmen that an opening of only 160 feet will materially and permanently injure commerce. The Chamber of Commerce of Saint Louis have sent here a large delegation to protest in the name of the people of the West."

Mr. COWAN said, "I will vote for the amendment with pleasure. I have had considerable experience in the navigation of Western rivers, and I have a very clear and distinct opinion of my own that nothing could be more mischievous to the interest of the carrying trade of the country than the construction of such low draw-bridges. I have no hesitation in saying that it would be better for the United States to-day to appropriate $1,000,000 for the construction of a high bridge across the Mississippi River 90 feet or 100 feet above low-water mark, with a span of 600 or 700 feet, than build a draw-bridge upon a stream of that character. I have no doubt that Western men will regret their action in a very short time if they allow these great streams to be obstructed by erections of this kind."

The consideration of the bill was postponed.

On May 29 (p. 2866) Mr. HENDERSON said, "I want a test vote on this amendment; I want the commission sent out to see if such low bridges are a necessity, and that high bridges cannot be built; if they report that these high bridges cannot be built, I shall be willing to let the low ones be built. A proposition is now pending in the Senate, authorized by the Committee on Commerce to be attached to one of the appropriation bills, to appoint a Board of Engineers to go and examine the river and report as to the proper kind of bridges to be constructed."

Mr. GRIMES favored low bridges; the towns were mostly low down on the river banks; high bridges would not suit them; bridges would never be built except at railroad termini; ultimately they might average one for every 50 miles; the detention would not exceed 15 minutes in passing each. He knew the Burlington and Quincy bridges, if authorized, would be begun this summer, and time would be lost waiting for report of commission. Bridges of 400-feet span would embarrass the companies; they would be forever unsafe. They never should exceed 200 feet, and, in case of a pivot-draw, 300 feet from end to end.

Mr. POMEROY said, "The river is an obstruction to the railroad. The time is coming, and I think has already come, when the commerce of the rivers must give way to some extent and be discommoded by the commerce of railroads. Let the companies themselves judge of the character of the structure. Let them be allowed to build it where they have to cross the stream, and only require them not to obstruct the navigation of the river more than such structures necessarily do. That is the language of the law in regard to bridging the Missouri River."

Mr. GUTHRIE said he was decidedly in favor of high continuous spans. Congress had compelled the Louisville bridge to be 90 feet high above low-water. "At the falls the highest rise is 44 feet; it has only reached this three times in the memory of man—1792, 1831, 1847. If the law had allowed us to build 70 feet above low-water, we would have been at work now. We have a draw-bridge at Nashville and have had a multitude of suits growing out of it, and are having them every year. I am satisfied that a skillful engineer who takes the whole subject into consideration, not only cost now, but trouble, vexation, and cost in the future, will decide in favor of continuous-span bridges."

The further consideration was postponed.

On the 14th of June, in the House (p. 3166), Mr. WINDOM introduced a bill for a bridge at Winona, and establish it a post-route, which was referred to the Committee on Post-Offices and Post-Roads.

On July 12 (p. 3769), Mr. ALLEY, chairman of the Committee on Post-Offices and Post-Roads in the House, reported back Senate bill No. 236, with amendments. As referred, it provided for bridges at Quincy, at Burlington, and at Hannibal.

The bill was amended to provide for a similar bridge at Prairie du Chien.

Mr. ALLISON asked, "Why not pass a general law so as to authorize every railroad to bridge that wishes to cross the Mississippi River?"

Mr. ALLEY said the committee was unanimous against the passage of such a law.

Mr. HOGAN asked, "If we had not passed a law directing the Secretary of War to make a survey of the Mississippi River to see where bridges can be built?"

Mr. ALLEY said, "I believe it is true, but I see nothing in this bill incompatible with that action, if this House sees fit to pass it." Amendment agreed to.

The next amendment was to expressly reserve "the right to alter or amend, so as to prevent or remove all material obstructions to navigation of said river by the construction of the bridges."

Mr. WILSON moved to amend so as to provide for a bridge at Keokuk. This amendment was agreed to.

Mr. WINDOM moved to amend by adding a section to provide for a bridge at Winona, with the same provisions as provided in Senate bill No. 263.

This amendment was agreed to after division—yeas, 80; nays, 34; absent, 68.

On the 14th July (p. 3811) this bill was further amended so as to include the provisions for bridges at Saint Louis, at Dubuque, Iowa, and for a bridge over the Missouri River at Kansas City, Mo. An amendment declaring the Clinton bridge a post-route was debated and rejected. The debate upon this amendment is given in the report upon Clinton bridge.

On July 16th (p. 3825) announcement was received in the Senate that the House had passed Senate bill No. 236.

On July 17th (p. 3854), in the Senate, Mr. RAMSEY reported Senate bill No. 236, and recommended concurrence in the House amendments.

On July 18 (p. 3898) the bill was taken up in the Senate. The first amendment by the House was for a bridge at Saint Louis, not to be a suspension or draw bridge, the bottom chord to be 50 feet above the city directrix at the main span; to have one span at least 500 feet in the clear or two spans of 350 feet in the clear each. If the latter is built, the span over the main channel shall be 50 feet above the city directrix. This amendment was agreed to.

The next amendment, providing for a bridge at Keokuk, Iowa, was agreed to.

Mr. BROWN offered an amendment to construct a submerged tubular bridge at Saint Louis, but afterward withdrew it.

The bill then passed; but on motion to reconsider by Mr. HENDERSON, he offered an amendment as follows:

Provided, That if the Board of Engineers authorized under the laws of the United States at the present session of Congress to examine the Mississippi River and make report on the subject of bridge construction thereon, shall find and so report that elevated bridges of continuous spans can be constructed and operated without greater expense to the company building them than draw bridges, and with less obstruction to navigation, then no draw-bridge shall be commenced or constructed under this act.

This Mr. HENDERSON advocated at length, and claimed that the authorizing of this Board of Engineers in the river and harbor bill meant that no bridge should be built till this engineer report was received. The Rock Island bridge is a nuisance which will, in the course of a few years, be declared such and taken down.

Mr. YATES replied, taking nearly the same ground as Senator Grimes, already quoted.

The amendment was rejected—yeas, 14; nays, 19; absent, 16.

Mr. HENDERSON offered an amendment that no draw-bridge should be erected prior to March 1, 1867. He again urged the importance of the engineer report before acting:

> If the Southern States are represented again in the Congress of the United States, if these bridges are put across the river they will have to come down. Mark what I tell you. I predict to-day that these bridges will not be permitted to stand if Congress hereafter can vote them down, because they will prove an obstruction to the river. I am satisfied of that.

Mr. GRIMES argued that the low bottom-lands of the Mississippi would not allow of high bridges, without embankments, that would bring the towns where the railroads crossed; high bridges were to him utterly impracticable.

Mr. COWAN asked, "Why put the bridge at the town?"

Mr. GRIMES explained the character of the Mississippi River.

Mr. HENDERSON replied to Mr. Grimes's assertion as to impracticability of high bridges.

Mr. BROWN sustained his colleague (Mr. Henderson). He was not opposed to railroads. There was a universal protest from the navigation interests against draw-bridges. Give us the bridge of a height of 50 feet above high-water, and make it a permanent structure, and we will forego our objection; we will take down our chimneys; we will change the construction of our steamers; we will dispense to a great extent with the height of our pilot-houses, and will adapt our system of navigation, as far as practicable, to facilitating the transit across the river.

Mr. JOHNSON advocated the amendment. He was counsel in the Wheeling bridge case for the bridge. It was erected by the authority of Virginia alone. The court recognized the right of the bridge, provided a draw was made so that boats could go through when they could not go under; but if a draw or some other such provision could not be made it must be abated by raising it to 90 feet above high-water. Congress passed a law, however, declaring the bridge a legal structure as it stood, and a majority of the Supreme Court held that that was within the power of Congress. Congress has a right to prescribe what draws bridges shall have, or whether or not to have any, and also the height of chimneys. We shall regulate these matters by law, but should wait for the report of the engineers before doing so.

The amendment was rejected—yeas, 11; nays, 25; absent, 13.

Mr. HENDERSON proposed to amend so that there should be no bridge other than a submerged tubular one built until after the report of the engineers.

The amendment was rejected.

The House amendments were then concurred in.

The House concurred in the Senate amendments, and the President approved the bill July 25, 1866.

(For further information concerning the views of members of Congress on this question see reports on Clinton and Saint Louis bridges.)

The building of the Quincy bridge was set on foot as soon as the act was approved, it already having been authorized by the States of Illinois and Missouri.

The provision of the river and harbor bill in regard to surveying the river did not specify a "Board of Engineers," and under it but one engineer was assigned to the charge of the work.

ABSTRACT OF PROCEEDINGS IN CONGRESS RELATING TO THE BRIDGE ACROSS THE MISSISSIPPI AT CLINTON, IOWA.

In December, 1865 (debates, page 135), Mr. PRICE, of Iowa, introduced a joint resolution in the House of Representatives, declaring this bridge a post-route and highway, which was referred to the Committee on Post-Offices and Post-Roads.

On July 12, 1866 (debates, page 3769), Mr. ALLEY, of Massachusetts, chairman of House Committee on Post-Offices and Post-Roads, reported Senate bill 236 (authorizing bridge at Quincy, Ill., &c., which had been referred to this committee), with amendments, one of which was to make the bridge at Clinton a post-road, provided it does not materially obstruct navigation. A very instructive discussion on this amendment took place in the House of Representatives on July 14, 1866 (pp. 3811–3818 of the debates).

Mr. WASHBURNE, of Illinois, offered an additional provision, that this section should in no way interfere with lawsuits now pending, and not take effect until the said bridge shall be made to conform in width of draw and all other respects with what is required to be done with reference to all other bridges referred to in this bill.

Mr. ALLEY would not accept this. He said his committee had given both sides a full hearing, and he had been directed, with one dissenting vote, to report a separate bill, but not being able to do so he put it as an amendment.

Mr. WASHBURNE opposed the bridge, as being built in defiance of law.

Mr. HOGAN opposed the Clinton bridge and all other bridges not giving at all times a clear height of 50 feet.

Mr. ALLEY said Clinton bridge had been in operation eighteen months.

Mr. WASHBURNE said the Rock Island bridge had been a damage to commerce already of $5,000,000, of which $2,000,000 was wrecks and damages. There were sixty-four steamboats lost, wrecked, or damaged, but because there was a question of jurisdiction arising, as well as other questions, the people who have suffered this great wrong are without a remedy. He said, "I have all the testimony here. The draw-openings at Clinton are 40 feet less than the width which the gentleman from Massachusetts has said is necessary for these other bridges. Why such discrimination in favor of this bridge? I have here the testimony of some 50 or 60 pilots and river men on the Mississippi River. The men interested in navigation say said bridge is a dangerous nuisance, materially obstructing the navigation of the Mississippi River; that we respectfully pray and hope that Congress will in no manner interfere with the course of justice by legalizing this bridge. We have here the affidavit of some 15 or 20 more pilots":

The undersigned pilots, captains, and experts in the navigation of the Upper Mississippi River, and owners of boats engaged in the navigation of the Upper Mississippi River, being duly sworn, state on oath that they believe the bridge constructed across the Mississippi River at Clinton, Iowa, as at present constructed, is a very material obstruction to the navigation of the Mississippi River; that they each and all have had experience and knowledge; that the same causes great risk to life and property in passing through the same, and causes great delay and loss to owners by detention on account of winds and darkness at times, when but for the bridge that portion of the river could be run with perfect ease and safety; that the said bridge is located where there is a curve in the river, and the piers are set at an angle of from 10° to 15° to the current, causing difficulties in the approach to the draw and danger of collision; that the draw is only 120 feet in width, and the difficulty is greatly increased when the boats have barges in tow; that the average width of a large boat, including guards, is 60 feet, and the additional width of two barges would be about 50 feet more, so that only 10 feet margin or 5 feet on each side is allowed; that where there is a current this margin is entirely too small for safe navigation even in calm weather, and that when there is any wind, or it is dark, the danger is greatly increased.

Mr. WASHBURNE continued:

"How was it in regard to the Rock Island bridge? Although we had no remedy, for want of jurisdiction, still it was such a nuisance that its friends finally gave it up. This House has passed an act at this session so that this bridge may be removed. But does this House know another thing? After the Senate had discussed for days this question of bridges, and passed the bill before the House, what did the Senate do? In the river and harbor bill they placed the following, which we adopted, and it is since become the law of the land."

This is the part of section 4 of the river and harbor act under which the examinations were begun, now being finally reported upon. At the end of the debate a vote was taken, and the amendment to constitute the Clinton bridge a post-route was lost—yeas, 54; nays, 66; not voting, 62.

On July 10, 1867 (see pages 391–398, debates), Mr. ALLEY, chairman of Committee on Post-Offices and Post-Roads, reported the bill (H. R. 965) declaring Clinton bridge a post-route.

Mr. WASHBURNE, of Illinois, opposed it, and claimed that its rejection last session should be final.

Mr. DAVIS said that no suit for damages had been brought against the company. There was a suit by way of indictment against it, in regard to which it asked the protection of Congress.

Mr. ALLEY said, "We want to connect with the commerce of the States, and if every time we propose to bridge the Mississippi River we are told that the commerce does not rightfully belong to the East, that it must pass through the Mississippi River and that you must not dam up that stream, it would have been a great deal better for the country if there had never been a Mississippi River. The committee made very patient investigation, heard both sides, and disinterested parties, too, and were unanimously of the opinion that if any bridge is proper this one is." He said he thought that 120 feet draw-opening was enough for this locality, and as good as 160 feet in some other places.

Mr. WASHBURNE, of Illinois, said there is a suit now pending about this bridge in the United States district court of Iowa.

Mr. ALLEY said there was no testimony to that effect. Before the committee it was denied.

Mr. HOGAN said the difficulty has been to find out the parties to be sued.

Mr. WASHBURNE said there were numerous cases of damage from this bridge.

Mr. FARQUHAR claimed that this bridge should be treated as the Wheeling bridge was—made a post-route.

Mr. ALLISON sought to have action deferred until General Warren's report could be made, as he had examined the bridge.

Mr. **Washburne** said they dare not trust that. The bill was passed—yeas, 101; nays, 43; not voting, 47.

On January 11, 1867, H. R. bill 965 was received in the Senate and referred to the Senate Committee on Post-Offices and Post-Roads. At the request of the chairman, Hon. Alexander Ramsey, of Minnesota, I was ordered to appear before this committee. I laid before them a map of the river and sections at the bridge together, showing the location of the bridge, with arrangements of spans and direction and velocity of the currents in the Iowa or main channel where the draw is located. At the same time everything ascertained by the survey was fully stated and explained in answer to questions of the members of the committee.

By request of the chairman I put the general facts and views in writing, as follows:

Washington, *February* 5, 1867.

Sir: In compliance with your request to furnish you the substance of my remarks made to-day, I have hastily put together the following in relation to the Clinton bridge across the Mississippi River.

The map I left with you shows the relation of the structure to the two parts into which the river is divided by Little Rock Island and the sand-bars across which the bridge is located and a considerable portion of the river above and below the bridge. My examinations were made nearly at low water.

The channel-way in which the pivot-pier and turning-bridge are placed is not less than 40 feet deep, and the current does not exceed two miles an hour. The clear spans each side of the pivot-pier are on the Iowa side 128 feet and 119 feet on the other.

Where the piers are situated the thread of the current is parallel with their lengths, but the current is at the time flowing on a curve sensibly parallel to the adjacent bank, and a steamboat is not able to head directly in the direction of the opening between the piers until she is quite close to them. The effect of this curve is further rendered objectionable by reason of an eddy formed below the point above the bridge, which eddy has an effect to vary the intensity and direction of the current near its outer margin so as to disconcert the plans of a pilot (in making his allowance for the swinging of his boat by the curved direction of the current) if he ventures too near the eddy. On this account the opening of the bridge on the Iowa side of the pivot-pier is seldom used. If we prolong the lines drawn through the middle of the draw-spans and perpendicular to the bridge till they reach the shore above the bridge, we find the distance of the one nearest the Iowa shore from the end of the pivot-pier to the shore to be about 500 feet, the other one to be about 1,000 feet. Steamboats at greater distances than these distances, less the length of the boat, could never be squarely opposite the openings left for them. These relations would produce very great difficulties to navigation if it were not for the low velocity of the current.

The effect of a side wind, is to require the pilot to place his boat's bow somewhat heading toward the wind, so as to make headway in opposite direction equivalent to the drift of his boat by the wind. She thus has to pass the piers somewhat obliquely and requires more space than in a calm. I am not able to state the effect of this in precise numbers for different cases, but it will evidently increase with the strengh of the wind and length of the boat and diminish in proportion to her speed.

When the pilot approaches the bridge in dark nights, he should not be looking into a bend as he has to do at the Clinton Bridge, but should have a straight reach before him, so that the bridge and the opening may be seen against the sky or its reflection on the water, and not confounded with objects on the bank beyond or their reflection from the water.

I am not prepared to state fully the extent of the obstruction which the bridge is or may become to navigation. To make it conform as far as practicable to the law of Congress authorizing bridges at Quincy, Keokuk, &c., would require almost the entire rebuilding of it; and in view of the necessities of communication east and west, it would not seem proper to compel this change to be made before time can be had for a fuller investigation of the subject, and a proper bridge built to take its place if its removal be ultimately decreed. But in view, further, of the great importance of the river navigation to the whole country in the future, I think nothing should be done in the way of legislation which will prevent it being removed if necessary hereafter, or which will furnish and excuse to other companies to build bridges across the river which fail in the least to fulfill every practical requirement of the navigation.

I am asked the question, "Do you think it practicable to build a draw-bridge which shall be no serious obstruction to navigation?" and this I answer in the affirmative,* for I consider it will be no serious obstruction if it allows boats to pass without danger at all times of night and day and all kinds of weather in which they are able to navigate the average of the bad places of the river. The temporary inconveniences of having to wait the passage of a train is quite inconsiderable; but if compelled to lie by, so as to lose many hours that might have been used in progressing on their way, then I should consider it a material obstruction, that the necessities of the case do not require and should be abated.

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*I do not think now that a draw-bridge can be built that will not seriously obstruct navigation.—G. K. W.

The following things are required in a good location for a draw-bridge on the pivot plan:

1st. The open spans of the draw should be in the channel-way at a point where it is permanent at all times and stages of the water, and both openings should be available.

In the Clinton bridge but one draw-span is useful.

2d. The current should not only be in the direction of the draw-piers where they are placed, but should have this same direction from 1,000 feet above the bridge to 300 feet below at least.

This requirement is not met by the Clinton bridge.

3d. Where the steamboat pilot, when approaching the bridge at night, could have the bridge and opening clearly defined against the sky or its reflection on the water surface.

This is not the case with the Clinton bridge.

4th. Where the passing boat and bridge are as much sheltered as possible from the most prevailing high winds.

This is as well accomplished by the present location as this vicinity admits of.

5th. Where the current is as gentle as the average of the river affords, and where the piers shall not produce any serious change affecting the regimen of the river.

The Clinton bridge meets these requirements.

6th. Where the most suitable land-approaches for the bridge and foundations for the piers can be found.

The Clinton bridge meets these requirements well. The draw should be opened promptly. The Clinton bridge does so.

It is practicable in some cases to find a location that naturally meets all these requirements, and if a bridge is needed where some are not found, then art and labor should be made to supply them. For it is a thing not to be endured that the great navigation interest should suffer a permanent injury in order that a bridge company might be saved a little inconvenience or expense.

The necessity for a safe and reliable transit across the Mississippi River is now so great that I recognize it as a fact that we can better do without the navigation altogether than to forego the privilege of crossing with certainty at all times and seasons; but this paramount necesity for bridging will produce the means of building even the most costly structures, and all reasonable expense should be willingly made that will leave the navigation practically unencumbered.

I have said nothing about the *width* of draw most proper, as that is regulated by the law. I think, however, that the law requires as great width as is at present practicable. The location of the bridge itself has such an important bearing on this question that the same spaces would have a far greater practical benefit in a good location than in a bad one, and I think it would have been desirable to have had a permanent commission appointed, composed of men of ability and integrity, that should have approved of every location proposed for a bridge on the Mississippi before a pier should have been allowed to stand in it.

Very respectfully, your obedient servant,

G. K. WARREN,
Brevet Major-General, United States Army.

Hon. ALEXANDER RAMSEY,
Chairman of Committee on Post-Offices and Post-Roads,
United States Senate.

On February 14, 1867, Mr. VAN WINKLE, of the Senate Committee on Post-Offices and Post-Roads, reported on H. R. bill No. 965 (printed report of committee No. 171), recommending its passage without amendment.

On February 21, 1867 (pages 1669–72 of the debates), the subject was discussed in the Senate.

Mr. VAN WINKLE made a statement of the case, in which he referred to General Warren's report and quoted from it. He said that General Warren was at the place only one day and thought the bridge was in a bad place on account of the curve; that but one draw-opening was available—the one on the Illinois side of the pivot—which was 119 feet wide;

the other one was 128 feet wide. He said General Warren was careful in his statements.

Mr. **VAN WINKLE** favored the bill, because the bridge record showed that of a great number of passages of boats through it there had been but little injury or loss of time. He further justified his advocacy of the bill, because the right is retained by Congress to alter or amend it at pleasure, thus enabling that body to require such alterations or additional constructions as will obviate all such objections as future experience may show to exist.

Mr. **JOHNSON** stated the case of the Wheeling bridge, in which he took part as one of the counsel. The United States Supreme Court ordered the bridge to be removed. Congress then declared it a post-route, which the same court held that Congress had the power to do, and that this act took away from the State of Pennsylvania the right to sue. The law was held to be retroactive, and to legalize the structure from the beginning. All suits against it fell at once.

Mr. **VAN WINKLE** said there was no suit against the Clinton bridge, except one pending for an injunction, commenced by the Northern Line Packet Company. A month's time was given them to offer proof, but they failed to do so.

Mr. **HENDERSON** thought there was a suit pending, and that the law ought to provide against interfering with pending suits at least. He offered an amendment.

Mr. **KIRKWOOD** favored the bill. He said General Warren was mistaken in saying the Iowa side of the draw was impracticable; the record shows that nearly half the number of passages under the bridge have been through that side of the draw.

Mr. **TRUMBULL** favored the bill. He said this bridge, thus constructed, is a part of the great line of railway reaching from the Atlantic to the Pacific Ocean.

Mr. **HENDERSON'S** amendment was rejected—yeas, 9; nays, 24; absent or not voting, 19.

The bill then passed.

The action of Congress received the approval of the President of the United States, and the bridge became a legalized structure.

A few personal remarks in relation to the debate in the Senate seem called for here. If Mr. **VAN WINKLE'S** remark "that I was there but one day" (which was a mistake) gave the impression that my examination was incomplete, it was unfortunate. I was there three days with a large surveying party. I also met there, by appointment, Mr. E. B. Talcott, the engineer who built the bridge, and gained all the knowledge that could be obtained at that stage of the river.

Mr. **VAN WINKLE** probably meant to convey the idea that my examination was only at one stage of the river, which was correct.

Mr. **KIRKWOOD'S** remark was also unfortunate, that I was mistaken in my statement in regard to the draw openings, in which I was unquestionably right. He probably misunderstood my statement, thinking it to refer to the passage on the west side of the island, instead of the west draw-opening.

HISTORY OF BRIDGING THE MISSISSIPPI RIVER AT SAINT LOUIS, MO.

The question of bridging the large navigable Western rivers rises to first importance here, considered from any point of view. It is especially interesting to navigation and engineering, and has received earnest attention from ablest men. An account including the earliest attempts will therefore be given.

Project of Mr. Truman J. Homer, city engineer, his allusions to earlier ones.—In the year 1855 a company was chartered to build a bridge at this place by the legislature of Missouri under an act entitled—

> An act to incorporate the Saint Louis and Illinois Bridge Company.

The company was organized with D. A. January, esq., as president. The financial crisis of 1857 and the war of secession deterred the company from further action, and the project lay dormant until 1864, when the legislature passed another act with a similar title. As both these charters had defects, considered in regard to the interests of Saint Louis, an amendatory act was passed in 1864, giving the requisite protection to that interest. This latter was affected through the exertions of a special committee of the board of common council of the city.*

In their report dated February 21, 1865, this committee recommended that the city should memorialize Congress to give authority confirmatory to the act of the legislature of Missouri; "and also that a law be passed prescribing the form and dimensions and regulating the construction of steamboats."

This report states that—

> The chimneys and pilot-wheels of steamboats may be so constructed as to admit of their being conveniently and expeditiously raised and lowered at will, so as to admit of their passing under an object 35 feet above the surface of the water.

On February 7, 1865, the board of common council instructed the city engineer, Mr. Truman J. Homer, to make a general plan of a bridge, and submit approximate estimates, which he did on the 11th of the same month.

It was for a horizontal tubular bridge crossing the low-water channel in three spans of 500 feet from center of piers at a height 64 feet above low-water mark, or about 30 feet above the city directrix. It was to have a railway in the middle and a wagon-way each side of it. The estimated cost was $3,332,200. The bridge was to cross a few blocks above the existing structure.

Mr. Homer states that Mr. Charles Ellet, upon invitation of the city council in 1839, submitted a project for a suspension bridge crossing at Market street, with one span of 1,200 feet, and two each side of 900 feet, each to cost $700,000; also that Mr. J. W. Bissell made in 1857 a plan for another suspension bridge, with one span of 1,500 feet, and that about the same time Mr. Roebling proposed to erect a bridge with a half-mile span. These proposed suspension bridges were probably for highway only. Mr. Homer was very much opposed to a suspension bridge at this place. For Mr. Roebling's plan for bridge at this place see further on.

Authorization of bridge by the United States.—On December 4, 1865, Senator B. GRATZ BROWN, of Missouri, gave notice of his intention to introduce a bill for authorizing the construction of a bridge across the Mississippi at Saint Louis. The Senate bill No. 38 (I have not seen a copy of it) was introduced in December and referred to the Committee on Post-Offices and Post-Roads.

Senator RAMSEY, chairman of the Committee on Post-Offices and Post-Roads, reported the bill back with a substitute as an amendment on March 21, 1866, and it was debated on March 22.

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* Reports of the city Engineer and | special committee | to the | common council | of the | City of St. Louis, | in relation to a | Bridge across the Mississippi River | at St. Louis | — — | St. Louis | McKey, Fishback and Company, printers and binders | 1865.

Section 2 provided that the bridge might be a pivot or other form of draw, or of continuous span; if the latter, to have an elevation not less than 40 feet above extreme high-water, measuring for such elevation from the level of the city directrix to the bottom chord of the bridge; spans to be not less than 250 feet, and piers parallel with the current; if a draw-bridge, must be at the same height, with a span over the main channel not less than 300 feet, and one adjoining span not less than 220 feet; the draw to be at an accessible and navigable point, with spans not less than 100 feet on each side of the pivot.

In the debate following the reading of the substitute, Mr. **Brown** said:

> I want the structure when built to be one worthy of the great States it is to connect, of such ample capacity as will permit the transit of the freight of all the railway lines that may hereafter center at the great distributing point of the continent. Let it be built, too, for the ages, of a material that shall defy time, and of a style that will be equally a triumph of art and a contribution to industrial development. No narrow view of expense, or contracted idea of the power of engineering skill, should induce us to permit any attempt at bridging the Mississippi River * * * that will seriously interfere with its navigation. The substitute has in certain details of height, measurements, and width of spans been thought not sufficiently guarded; I have, therefore, submitted amendments *in lieu* of section 2.
>
> They are, in the first place, that the bridge shall be 50 feet in height above high-water mark, or what is substantially high-water mark, the elevation line of the city directrix. *Second*, have one span 600 feet in the clear, or else two spans 450 feet in the clear each. *Third*, no span over the water-way at low-water mark less than 200 feet in the clear. * * *
>
> From 1860 to 1865, the river did not come up to within many feet of the city directrix. In the last 25 years only three times has the water been above it,—1851, 1858, 1844; on one of these occasions only 3 feet, on another 4 feet, and on the other 7 feet, altogether for a space of 3 or 4 days at each time.

Mr. **Brown's** amendment also provided that the bridge should not be a suspension bridge or draw-bridge, with pivot or other form of draw.

Mr. **Henderson** asked, "Is the amendment substantially in accordance with the recommendation of the Chamber of Commerce of Saint Louis?"

Mr. **Brown** answered, "It is exactly in accordance with that, with the simple provision that it substitutes the fixed point of the city directrix for the questionable one of extreme high-water."

Mr. **Henderson** remarked, "I was of the impression that the water more generally rose above the city directrix."

Mr. **Brown** replied, "No, I have the water-lines for the last 25 years."

The amendment of Mr. Brown was then agreed to.

Mr. **Doolittle** asked, "Is 50 feet above the directrix sufficient, so as not in any respect to interrupt navigation?"

Mr. **Grimes** added to this question, the condition, "Provided they lower their chimneys."

Mr. **Brown** replied, "They will have telescopic chimneys. It will not interfere with the pilot-houses, or anything of that sort."

The bill was then pased in the Senate.

Remarks.—It should be noticed here that Mr. Brown's amendment fixing the height of the bridge 50 feet above extreme high-water, as recommended by the Chamber of Commerce (which represented the navigation interests), had the effect to put the bridge 7 feet lower than the steamboatmen and navigation interests had consented to. Seven feet above the city directrix, the known height of the high-water of 1844, was as fixed a height as the directrix itself. There was nothing uncertain about the extreme high-water mark of 1844. Other floods might not come up so high. Some other floods might go higher.

The navigation interests apparently did not appreciate this change until they saw the first arch about being completed in the summer of 1873. Then they petitioned the Secretary of War to appoint a Board of Army Engineers to see what could be done, as will be described further on.

The Senate bill No. 38 was received in the House on March 22, 1866, and on April 2 it was referred to the Committee on Commerce, but I am not aware that it was ever reported back.

In the Senate, on July 17, Mr. Ramsey, chairman Committee on Post-Offices and Post-Roads, to which Senate bill 236 had been referred, with amendments made by the House, reported it back with an additional amendment.

On July 18 it was considered. This amendment provided for building the bridge at Saint Louis as proposed in Senate bill 38, with the modification requiring that there should be one span of 500 feet in the clear (instead of 600 feet), or two spans of 350 feet each (instead of 450 feet each). This, together with all the House amendments, was agreed to.

On July 21, the House concurred in the Senate amendment. The act was approved July 25, 1866.

Project of the convention of engineers called together by Mr. L. B. Boomer in the summer of 1867.—In 1855, the legislature of Illinois chartered a company to build a bridge across the Mississippi at Saint Louis, styled "The Illinois and Saint Louis Bridge Company." Mr. Boomer, representing this company, of which Mr. A. Anderson was the engineer, called together several distinguished engineers to consider the advisability of building the bridge with one span of 500 feet in the clear, or with two spans of 350 feet in the clear, an option made in the United States law.

The proceedings and report of the assemblage are published in a pamphlet of 100 pages, 8vo, besides three sheets of bridge-strains.*

Mr. William J. McAlpine was chosen president, and Mr. T. McKissock secretary. In his introductory speech the president said:

> The Federal and State laws under which the bridge is to be built require an elevation sufficient to allow steamers, with their unnecessarily high chimneys, to pass at the highest stage of water, and with spans of unnecessary width for the navigation. "The men of science" must thus far "bow to the men of law," and it is this necessity which has compelled the officers of the bridge company to bring to the consideration of these grave subjects such an array of the "men of science."

Whatever point this remark quoted from Sir Francis Head had when made in regard to the subserviency of men of science to men of law, it seems to be wanting in this case. As shown in the preceding abstract from the Congressional debates, the advocates of the bridge admitted that the chimneys must come down to pass it at ordinary high-water, and they only claimed that the pilot-houses would not have to be lowered; but even this was not a bad enough statement for the navigation interest, for on all the large and economical boats the pilot-houses were too high to pass under the bridge at ordinary high water. If the true men of science did "bow to the men of law," it was in having the ability of the scientific engineer underestimated. The man who really stood "cap in hand" was the navigator, appealing for his rights against a rival and unscrupulous interest, and looking to both the man of law and the man of science for protection. The argument of necessity, which knows no law, had been evoked! Bridges must be built! Long and high spans are impracticable! Navigation must give way! said the advocates of poor bridges.

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*Proceedings and report | of the | Board of Civil Engineers | convened at St. Louis, in August, 1867, | to consider the subject of the construction of a | Railway and Highway Bridge | across the Mississippi River at St. Louis | —.— | St. Louis, | George Knapp & Co., Printers and binders, | 1867.

The matter before the convention was divided into five different subjects and submitted to five different committees:

First. On the regimen of the river and the character of its bottom, Messrs. Truman J. Homer, Missouri; J. B. Moulton, Missouri. The report of this committee (seven pages 8vo) contains valuable data on the questions submitted.

Second. On the foundations and piers, Messrs. E. S. Chesbrough, Illinois; William J. McAlpine, New York; General W. S. Smith, Michigan; George A. Parker, Pennsylvania; L. J. Fleming, Alabama; C. L. McAlpine, Massachusetts; and A. Anderson, Kansas. Mr. Chesbrough, the constructor of the lake-tunnel of the Chicago water-works, was chairman; Mr. C. L. McAlpine, constructor of the pneumatic foundations of a bridge across Harlem River, secretary. Of the other members, it may be mentioned that Mr. W. J. McAlpine constructed the dry-dock of the Brooklyn navy-yard, using coffer-dam in 50 feet water, where he also made valuable observations upon the use of common wooden piles. General Smith had sunk the pneumatic foundations for the bridge at Omaha, and on the Savannah River, Georgia, and had experience in several other important and difficult foundation works. Mr. Parker had constructed the very difficult work of making foundations for the bridge over the Susquehanna River at Havre de Grace. Mr. Fleming had also constructed pneumatic foundations on the Santee and Pedee Rivers. This committee thoroughly discussed the subject.

The bed-rock on the west shore is 23 feet below low-water; 500 feet east of that, 64 feet; at 500 feet farther east, 90 feet below low water; at 500 feet still farther east, rock had not been found, but boring had only been carried down 68 feet below low water. The great depth at which rock is found, except at the west shore, "induced the consideration of plans of foundation entirely independent of any support to be gained from it, except where it could be reached within a reasonable depth." They regarded a depth of 45 feet below low water as a safe limit of the scour.

At a joint meeting with the committee on regimen of the river and character of bottom and with the committee "on the superstructure and approaches"—

> It was unanimously agreed to adopt the minimum spans allowed by the law for crossing the channel * * * as more economical, less hazardous in construction and maintenance, and affording ample accommodation to the commerce of the river and the port of Saint Louis.

These spans were to have horizontal chords. It was also resolved,

> That we would recommend spans of less than 350 feet in the clear if the Federal laws permitted such reduction.

The committee estimated that with 350-foot spans and the bridge loaded, the weight on the foundations of a pier, if built solid, would be 8,500 tons. This, if borne by wooden piles, would require 210 of them, each pile supporting 40½ tons.

> After a careful consideration of the subject, this committee agreed that the following plans would be entirely practicable:
>
> First. With the piers placed upon foundations of hollow iron piles, on the purely pneumatic principle, either to the rock, or, where it lies at too great depth, by an expansion of their base, or driven by the use of sand or steam siphon-pumps.
>
> Secondly. With piers of masonry carried below the scour of the river by the use of iron caissons, as was practiced at the different piers of the Susquehanna Bridge, and resting either on wooden piles or small pneumatic piles.
>
> Thirdly. With piers of masonry carried below the scour by the use of a combination

of inverted and direct iron or wood caissons; the inverted caisson filled with masonry by the pneumatic process and the direct caisson in the ordinary way.

Fourthly. With the piers laid up either of solid or galleried masonry.

Fifthly. That instead of masonry, the iron pneumatic piles may be extended upward to the bridge-seat as columns of support, and strongly braced on the lines of the river and the axis of the bridge.

The third committee was on "the superstructure and approaches." This was composed of Messrs. S. S. Post, of New Jersey; R. M. Shoemaker, of Ohio; L. J. Fleming, Alabama; O. Chanute, Kansas; T. B. Blackstone, Illinois; and William J. McAlpine, New York.

The design of superstructure they estimated for was trusses of Mr. Post's pattern, four of them per span, having a single track railroad, two highways 17 feet in the clear, and two sidewalks outside of the whole.

It was decided at a joint meeting of the committees to adopt the two spans of 368 feet from centers, or 350 feet in the clear, next the Saint Louis side, and to place four spans of 264 feet from centers between them and the Illinois shore. A single span on each side was to carry the bridge over the levees on each side.

It is stated in this report that spans 500 feet in the clear will cost more than twice as much per foot as for 350 feet in the clear. These estimates were for a bridge with a moving load of about 7,300 pounds per foot. The cost of the superstructure and approaches was estimated at $3,638,920.

The fourth committee, on the commerce and navigation, consisted of Messrs. T. J. Homer and F. A. Churchill, Missouri. Their report is embodied in the general report of the convention.

The fifth committee, on the commerce crossing the bridge, was composed of Messrs. T. B. Blackstone, Illinois; A. Anderson, Kansas; T. McKissock, Missouri; and Charles A. Tucker. This committee made a special report of four 8vo. pages. Mr. Tucker did not sign the general report.

The principal features of the committee reports were accepted and embodied in a general report consisting of fourteen pages, 8vo. The bridge was to cross a few blocks above Washington avenue, in Saint Louis. The estimated cost of the whole work as adopted in the general report was as follows:

For land damages	$386,000
Foundations, piers, and masonry	2,541,007
Superstructure and approaches	3,638,920
	6,565,927

From the report and proceedings it does not appear that any engineers took part in the deliberations other than those named above as serving on committees. All their names are attached to the general report, and, in addition, the names of thirteen others, being all those named in the printed report after the name of Mr. S. S. Post.

PROJECT FOR BRIDGE BY CAPT. JAMES B. EADS, SUBMITTED TO THE BRIDGE COMPANY IN MAY, 1868.

The bridge company authorized by the legislature of Missouri and the one authorized by the legislature of Illinois were united under the title of the Illinois and Saint Louis Bridge Company, and Capt. James B. Eads was appointed engineer-in-chief.

The first of his reports that I have seen consists of 72 pages, 8vo.

with one map of the locality and perspective view, with several woodcuts illustrative of principles governing the construction of bridge-spans, as well as representations of several of the most celebrated bridges in the world.*

This is accompanied by an appendix containing 77 pages, 8vo., separately paged, being "Mathematical Investigations and Computations for the Construction of the Illinois and Saint Louis Bridge.—Missouri Republican Print." This has some small diagrams and three sheets of diagrams.

Captain Eads was assisted by Col. Henry Flad, civil engineer, and Mr. Charles Pfeifer. The mathematical work was verified by Prof. C. W. Chauvenet, LL. D., &c.

The report is an interesting and instructive contribution to the bridge literature of the period. It at length discusses the report of the civil engineers made the year before, and rejects their conclusions. The bridge proposed in Captain Eads's report "will have three spans each formed with four ribbed arches, made of steel. The center span will be 515 feet and the side ones 497 feet each in the clear."

I will not copy the details of the design from this report, as they were modified and improved upon in the report to the bridge company made in October, 1870. It was designed for two separate railway-tracks, to allow of passing both ways at once, and above this a roadway for ordinary vehicles and street-cars, 34 feet wide, and two sidewalks, each 8 feet wide. The service required of it was therefore very large. The greatest load was calculated to be 7$\frac{2}{10}$ tons per linear foot, including its own weight, which was 4 tons per linear foot.

The design was claimed to be one of great economy over any other form of bridge that would afford the same service; the total estimate of cost was as follows:

Superstructure	$1,460,418 30
Substructure	1,540,080 00
Approaches	520,397 24
Tunnel	410,477 55
Land and land damages	539,900 00
Railroad	25,680 00
Total	4,496,953 09

The work on the Saint Louis abutment was begun in 1867, a coffer-dam having been constructed, and excavation carried to the bed-rock upon which the masonry was laid. About 1,040 cubic yards had been laid by the 15th of March, 1868, bringing the work up about 12 feet above low-water, when work was arrested by the rising of the river.

By act of Congress approved July 20, 1868, the consolidation of the two bridge companies was sanctioned, and the privileges conveyed in the act approved July 25, 1866, were granted the new company, and it was also made obligatory to build one span at least 500 feet in the clear.

USES MADE OF THE REPORTS ON THE SAINT LOUIS BRIDGE TO INFLUENCE CONGRESSIONAL LEGISLATION IN REGARD TO BRIDGING THE OHIO RIVER.

In the spring of 1868 a bill was introduced in Congress to authorize building a bridge at Paducah, and another to extend the provisions of the act of July 14, 1862, authorizing the Steubenville bridge (which was general in its application as far down the Ohio as the mouth of the Big Sandy), so as to authorize a bridge of the same spans anywhere above the mouth of the Licking River. This last provision was made especially to benefit the interest contemplating the construction of a railway and highway bridge between Cincinnati, Ohio, and Newport, Ky. Great interest was at once aroused on the subject, and many petitions, memorials, &c., were addressed to Congress. The navigation interest contended for a clear span of 500 feet, and not only opposed the extension of the law authorizing the Steubenville bridge, which required a clear span of only 300 feet, but endeavored to have it repealed altogether. In the last effort they were opposed by the interest of the Baltimore and Ohio Railroad Company, who were about to build bridges under this law at Bellaire and Parkersburg.

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* Report | of the | Engineer-in-Chief | of the | Illinois and St. Louis | Bridge Company. | St. Louis, May, 1868. | St. Louis | Missouri Democrat book and job printing office, corner of Fourth and Pine streets, | 1868.

The Senate Committee on Post-Offices and Post-Roads were instructed to report a general bridge law, and the chairman sent for me to aid him in its preparation. I then made an examination of the Steubenville bridge, and submitted an estimate of cost for a single-track railway, having a clear span of 500 feet, and two adjoining of 300 feet, at about $800,000. The object of this was to show that their cost would not render them impracticable, for the estimated cost of the bridge at Saint Louis, about $4,500,000, by Captain Eads, and about $6,500,000 by the convention of engineers, had placed a strong argument in the hands of the opponents of long-span bridges, who concealed the fact that these estimates were for kinds of bridge providing for quadruple the service of a single-track railway.

The whole subject is fully set forth in the report of the committee dated July 16, 1868 (Rep. Com. No. 168, Fortieth Congress, second session), and they submitted a bill requiring 500-foot spans.

This proposed law was discussed in the Senate on July 21, and strong objection was made to it on the ground that 500-foot spans were impracticable, and this was enforced by citing especially the report of the convention of civil engineers on the Saint Louis bridge. A small pamphlet with extracts from that report was printed, and distributed to members of Congress. No final action was taken that session in regard to the general law.

A kind of compromise was made with regard to the Newport and Cincinnati bridge, which, however, was deceptive, and occasioned much future trouble. Believing that the report of the civil engineers' convention at Saint Louis was being made to subserve ends never intended by its framers, I addressed a circular letter to the signers of that report. Answers, containing much information, were received from twelve of them, and one of them sent me also a communication of much interest from General C. Shaler Smith, civil engineer.

This circular and the letters are given in order following:

Circular.

UNITED STATES ENGINEER'S OFFICE,
Saint Paul, Minn., December 21, 1868.

Member of a Convention held at Saint Louis in August, 1867:

GENTLEMEN: I respectfully request your consideration of the use that has been made of your report in a pamphlet circulated among members of Congress at the last session, and would like to be informed by you, individually, how far you intended to decide the question of bridging the great navigable Western rivers. It did not seem to me that anything more was intended by the convention than to "recommend to the parties in interest," viz, "the bridge company," what you deemed was for their interest, and I think that may be clearly inferred from your report. Nevertheless, there are expressions used in different places in it which seem to indicate that the conclusions reached were general in their application, and I have thought it best to refer the matter to you.' I have taken from the pamphlet to which I call your attention its title-page, and all there is quoted from your report.

In order that you may understand why it is that *I* bring this matter before you, I will state:

That in August, 1866, I was assigned to the duty of collecting information in relation to bridging the Mississippi River between Saint Paul, Minn., and Saint Louis, Mo., under a joint resolution of Congress passed just previous to my being thus assigned. I have been engaged upon this, with other duties, ever since, reporting progress from time to time to the Chief of Engineers, United States Army, and conferring and communicating with the Senate Committee on Post-Offices and Post-Roads at each session.

At the last session, the question of bridging the Ohio River was brought prominently forward, and I was consulted by this same committee in relation thereto. The report of this committee you can probably obtain by writing to a member of Congress. It forms printed Senate Report Committee No. 168, Fortieth Congress, second session.

The substance of what I am responsible for in that report is, that a 500-feet span (not a suspension one) is practicable, and with the contiguous spans of the ordinary length, with single track, at an expense not greater than for such bridges already built in this country, and that the interests of the navigation should determine whether such long spans were necessary, as it might be in some cases and not in others. I did not think then that I was at variance with the Saint Louis convention; that convention had decided the question as far as it related to the bridge company's interest, and to the effect, that the cheaper the bridge the better for them, while I had given my opinion that the necessities of navigation should decide it, provided these were not so exacting as to be practically prohibitory to bridges.

The debates on the subject in the Senate on July 16, 17, 21, and 22 (see Globe), show that very considerable importance was given, in the minds of some members of the Senate, to the extracts from the report of the Saint Louis convention, one Senator using the following language: "I wish to read a few extracts from a longer report now in the hands of the Senator from Indiana. As we cannot get any other reports to know whether this [the report of the Senate committee] is right or wrong, I shall be inclined to rely on this report of 25 civil engineers, one of them, however, being from the United States Army." Extracts were then read from this pamphlet, and the Senator concluded: "Mr. President, I am bound to believe, until I see something to the contrary from some authoritative source, that this idea of a 500-feet span is a mere notion, gotten up by one opposing interest against another."

I hope you will not take this reference of the matter to you, by me, as an unwarrantable intrusion. I would be obliged to you for such answers as you choose to make, and I would like to have them sent me with the understanding that they may be officially used by me in my reports.

I, myself, attach the highest value to the decision of a body composed of such distinguished engineers as composed that convention, and as it is not a permanent organized body, I have addressed this to you individually. The weight which your decision must carry with it must be my excuse for endeavoring to ascertain "authoritatively" what that decision practically was, and its extent and application. The question has not yet been disposed of in Congress.

Yours, respectfully,

G. K. WARREN,
Major of Engineers, Brevet Major-General, United States Army.

The following are the extracts from the report of the convention as published in the pamphlet:

FACTS RELATING TO THE BRIDGE QUESTION.

300-feet span sufficient and safe, and fixed by Congress for the Ohio River—500-feet span hazardous, and an untried experiment—Suspension bridge prohibited by Congress at Saint Louis—Opinions of eminent engineers and bridge-builders—Towage on the Ohio River.—Bradley & Power, printers, 149 Main St., Cincinnati, O., 1868.

Convention of Engineers at Saint Louis.

[Extracts from the proceedings and report of the board of civil engineers convened at Saint Louis, in August, 1867, to consider the subject of the construction of a rail and highway bridge across the Mississippi River at Saint Louis.]

The following persons took part in the proceedings of the convention, and signed the report, in which they all concurred. Report, pages 90, 91:

WM. J. MCALPINE, Civil Engineer, New York.
GEORGE A. PARKER, Civil Engineer, Pennsylvania.

E. S. CHESBROUGH, Civil Engineer, Illinois.
W. S. SMITH, Civil Engineer, Michigan.
L. J. FLEMING, Civil Engineer, Alabama.
A. ANDERSON, Civil Engineer, Kansas.
C. L. MCALPINE, Civil Engineer, Massachusetts.
T. J. HOMER, Civil Engineer, Missouri.
J. B. MOULTON, Civil Engineer, Missouri.
T. B. BLACKSTONE, Civil Engineer, Illinois.
I. MCKISSOCK, Civil Engineer, Missouri.
R. M. SHOEMAKER, Civil Engineer, Ohio.
O. CHANUTE, Civil Engineer, Kansas.
F. A. CHURCHILL, Civil Engineer, Missouri.
S. S. POST, Civil Engineer, New Jersey.
R. B. MASON, Civil Engineer, Illinois.
JULIUS W. ADAMS, Civil Engineer, New York.
W. E. MERRILL, Brevet Colonel United States Engineers.
WM. E. WORTHEN, Civil Engineer, New York.
JOHN E. HENRY, Civil Engineer, Iowa.
S. F. JOHNSON, Civil Engineer, Rhode Island.
L. H. CLARK, Civil Engineer, Illinois.
JAS. H. MORLEY, Civil Engineer, Missouri.
E. H. JOHNSON, Civil Engineer, Illinois.
W. W. EVANS, Civil Engineer, New York.
F. HUBBARD, Civil Engineer, New York.
D. C. JENNE, Civil Engineer, New York.
IRA SPAULDING, Civil Engineer, New York.

The objects of the convention, and the class of men of whom it was composed, will appear from the following passages in the opening address of the president, William J. McAlpine, of New York, the oldest practicing civil engineer in the United States (Report, pp. 4, 5, 6, and 7):

"The problem which is presented to us is not only one of the most interesting ones of the profession, but also involves other considerations of the highest commercial importance.

"In preparing plans for bridging the Mississippi, we must give due attention to the relative importance of the navigation of the river, and of the traffic which the bridge is to accommodate. The former is one of the most important inland water-channels in the world, and the latter is to form a connecting link in one of the most important lines of land transport across the continent.

* * * * * * *

"Heretofore the traditional importance of the navigable water-lines has controlled legislation and the legal tribunals almost wholly in their favor. The last third of a century has developed a traffic over the land lines of transport of such importance that modern legislation and legal decisions have been compelled to concede the right to carry railroads across the navigable waters; and although this legislation has not yet risen to the correct view of the question (namely, that they should each yield and have the right of occupancy in proportion to their relative importance), yet it has made such progress that, as Sir Francis Head not long ago said in regard to the Britannia bridge, 'the man of science must no longer, cap in hand, bow to the man of law.'

"The Federal and State laws, under which the bridge at this place is to be built, require an elevation sufficient to allow steamers, with their unnecessarily high chimneys, to pass at the highest stage of water, and with spans of unnecessary width for the navigation. 'The men of science' must thus far 'bow to the men of law,' and it is this necessity which has compelled the officers of the bridge company to bring to the consideration of these grave subjects such an array of the 'men of science.'

"Although we have been convened at the request of one of the rival companies, yet we are to consider all of the questions bearing on this subject without reference to any particular plan or company. We have among our numbers the pioneer of the pneumatic pile foundations and his eminent successor; the constructor of the caisson-built piers of the Susquehanna; the builder of the Lake Michigan tunnel; the veteran bridge-builder who has made the longest wooden span in the country, and has now presented us with designs of those in iron, to meet even the requirements of the 'men of law.'

"We have with us eminent representatives from our great national polytechnic and from our highest civil universities, and I may venture to say that the result of our deliberations is looked forward to with great interest by those both in and out of the profession, and that the belief is strongly entertained by the commercial, financial, and professional gentlemen interested in this and similar enterprises that your combined science and skill will develop the best method of overcoming the difficulties to be met in accomplishing this great undertaking.

* * * * * * *

"From such an array of engineering talent we may expect a complete elucidation of the important questions before us.

* * * * * * *

"The law requires a bridge to be constructed with one of its spans not less than 500 feet clear opening, or with two spans of not less than 350 feet each.

"You will be called upon to consider whether the saving to be effected by the cost of the foundation and piers will be equal to the increased cost of the superstructure in spans of such great length, and whether suitable materials can be procured and put together so as to sustain their own weight and those of stationary and passing loads."

For the purpose of facilitating the business before the convention, a resolution was adopted requesting the chair to appoint committees on the following subjects (Report, p. 8):

1. On the regimen of the river and the character of its bottom.
2. On the foundations and piers.
3. On the superstructure and approaches.
4. On the river commerce and its navigation.
5. On the commerce crossing the bridge.

[Extracts from the minutes of the proceedings and discussions of the committee on foundations and piers.

It was decided that the discussions should be with open doors, and that any member of the convention, or any person interested in the subject who expressed a desire to that effect, should be invited to be present during the discussions. (Report, p. 19.)

And the committee, in conjunction with the committee on the regimen of the river, having had the subject referred to them under consideration for two days, their further proceedings were as follows (Report, pp. 34 to 36):

LENGTH OF SPAN.

The further consideration of the questions involved in the construction of the proposed bridge requiring consultation between the committee on the regimen of the river and that on superstructure, and in order that some of the general points affecting the calculations of each of the committees might be agreed upon, a conference was therefore had with the two committees named, and a joint meeting was held to consider these points, consisting of the following-named gentlemen:

T. J. Homer, J. B. Moulton, H. C. Moore, E. S. Chesbrough, W. S. Smith, George A. Parker, L. J. Fleming, A. Anderson, C. L. McAlpine, S. S. Post, R. M. Shoemaker, O. Chanute, T. B. Blackstone, W. J. McAlpine.

The chairman of the committee on superstructure having made elaborate drawings, estimates, and descriptions of plans, and having placed them all before the joint committee, the members thereof proceeded to discuss the general subjects, and to compare the results of the other experiences applicable to the case so far as to satisfy themselves that the calculations, &c., referred were substantially correct and sufficient to enable them to proceed with the further general consideration of the questions involved, which were presented by Mr. McAlpine, as follows:

1st. Of the two alternatives for the spans for the main channels allowed by law, which should be adopted?

2d. What spans (within the limits of the law) are best for the remainder of the distance?

3d. What dimensions and accommodations of the bridge are necessary for the convenience of its traffic?

4th. What will be the approximate cost on the basis which shall be decided, in reply to the foregoing propositions?

And the following preamble and resolutions were agreed upon:

Whereas the Federal law authorizing the construction of the bridge across the river at Saint Louis requires, as per section 12, as follows:

"SEC. 12. *And be it further enacted*, That the bridge authorized by the preceding section to be built shall not be a suspension bridge, or a draw-bridge with pivot or other form of draw, but shall be constructed with continuous or unbroken spans, and subject to these conditions: First, that the lowest part of the bridge, or bottom chord, shall not be less than fifty feet above the city directrix at its greatest span. Second, that it shall have at least one span of five hundred feet in the clear, or two spans of three hundred and fifty feet in the clear of abutments. If the two latter spans be used, the one over the main steamboat-channel shall be fifty feet above the city directrix, measured by the lowest part of the bridge at the center of the span. Third, no span over the water at low-water mark shall be less than two hundred feet in the clear of abutments";

And whereas, the said law confines the question of the span over the main channel to one of five hundred feet, or two of three hundred and fifty feet each (clear width);

And whereas, by careful calculation, the amount of the materials and the cost of that portion of the bridge above referred to, arranged on the most judicious and economical spans for the remainder of the distance, will involve an extra cost of about three-fourths of a million of dollars;

And whereas there has been no bridge of the character of that which (in our judgment) is required in this place yet constructed, to furnish us with any reliable and certain data on the serious questions of materials and workmanship in spans of such great length: It is, therefore,

Resolved, That we, as practical engineers, cannot conscientiously recommend to the parties in interest to venture upon the construction of spans of as great length as the maximum one prescribed by law, and that therefore we do recommend for adoption the minimum spans allowed by the law, as more economical, less hazardous in construction and maintenance, and affording ample accommodation to the commerce of the river at the port of Saint Louis.

It was also

Resolved, That, in view of all the circumstances of this case, we would recommend spans of less than 350 feet in the clear, if the Federal law permitted of such reduction.

[Extracts from the report of the committee on the foundations and piers.]

At the joint meeting of the committee, and those on the regimen of the river and superstructure, it was unanimously agreed to adopt the minimum spans allowed by the law for crossing the main channel, namely, two of 350 feet each in the clear; and the following preamble and resolutions were agreed upon (the preamble and resolutions previously quoted, Report, p. 42).

* * * * * * *

The committee examined the estimates of the chief engineer as to the cost of the foundations and piers, and are satisfied that they will be sufficient in amount.

* * * * * * *

A careful revision of the details of the chief engineer's estimate satisfies the committee that a sufficient sum in gross has been arrived at to amply cover the cost of the foundation and piers, upon either of the plans which have been recommended by it for adoption at this place. The aggregate amount for these items is $2,541,007.

In conclusion, the committee would say that in their deliberations they have been influenced by strong professional interest in a work whose magnitude demanded of them the best knowledge, consideration, and judgment that could be applied to it.

* * * * * * *

Many of the committee were notified at an early day that this question would be brought before them, and at the meeting it was found that much individual examination of the subject had already been made, assisted by the practical experience which they had gained in the construction of their works. In committee, therefore, a varied and comprehensive knowledge was developed, which greatly assisted in the solution of the difficulties to be met with at this place, and it enabled the members, after free discussion, to arrive at results with great confidence (Report, pp. 44, 45).

[Extracts from the report of the committee on superstructure and approaches.]

The further consideration of this subject involves a knowledge of the regimen of the river at this place, and of the foundations of the piers. Therefore, the committee on this subject requested a joint meeting of those to whom these questions had been referred. Such a meeting was held, and after an elaborate discussion of the whole subject it was unanimously resolved by the members of the joint committee "That, under the circumstances of the case, it is expedient to construct the spans over the main channel of 350 feet in the clear," and they expressed by resolution "their unqualified disapprobation of spans of 500 feet." The joint committee also recommended the arrangement, above described, of spans of 364 feet between the main channel and the east shore.

It was proved in joint committee that the cost of a span of 520 feet (500 feet in the clear) will be more than twice as great per foot of bridge as a span of 368 feet (350 in the clear) and not less than three times as great as a span of 304 feet; consequently, the cost of one span of 520 feet will be equal to two spans of 368 feet and one and a half spans of 264 feet; that is, for the cost of one span of 520 feet no less than 1,150 feet of bridge in spans of 368 feet and 264 feet may be built (Report, p. 48).

The committee give the results of elaborate estimates of the weight of the bridge, and the loads it will have to sustain, and of the consequent strains that will come on its several parts; and conclude as follows:

"Detailed and close estimates have also been made of the quantities and cost of material required to fully meet all the strains as thus computed, which detailed estimates have been placed at the disposal of the Illinois and Saint Louis Bridge Company, amounting in the aggregate to $3,638,920. This sum, however, includes, besides the superstructure of the bridge as above described, a span of 160 feet, single track, across

Cahokia Creek, the embankments of earth forming the approach, paving the carriage-ways, flagging the sidewalk of the approaches, and 6,000 feet of railway-track. It is, in other words, the cost complete of that part of the work referred to this committee." (Report, p. 54.)

[Extracts from the general report of the convention.]

The joint committee on the regimen of the river, on the foundations and piers, and on the superstructure, discussed the alternative proviso of the law in regard to the length of the spans across the main channel, and unanimously agreed that it was inadvisable to adopt the span of five hundred feet clear opening, on account of the difficulty of procuring suitable materials of the proper form, size, and workmanship required to meet the extraordinary strains to which some of the members of the truss would be subjected; the increased hazard of its construction and maintenance; the large additional cost of the whole structure by the use of the long span, and because the necessities of this case do not require the use of one of such great length, for which there is no engineering precedent.

The joint committee, therefore, adopted the alternative of two spans of 350 feet clear width over the main channel, and spans of 264 feet over the remainder. The board entirely concurred in the conclusion of the joint committee (Report p. 79).

The report of the committee on the river commerce and its navigation is embodied in the general report, and the following paragraphs are copied from it (Report, pp. 85, 86, 87):

"In times gone by, before lines of railway radiated in every direction, making a rapid and sure conveyance to all parts of the country, it might have been urged with much force that everything which tended to retard the river navigation was a matter of public importance and to be protested against. But now the case is entirely different; we no longer look to steamers as a means of passenger conveyance; as a general thing, even pleasure travel usually takes the mode of quickest transit from point to point.

"Time is the great element which governs all our actions, and the want of it is such a peculiarly American characteristic that the man who should propose a business trip to Saint Paul, Cincinnati, or New Orleans by water would be considered a little short of insane.

"One of the immediate and principal effects of bridging the Mississippi at this point is thought to be the establishment of a line of demarkation between the upper and lower river trades.

"As the class of steamboats adapted to the lower river are quite different from those on the upper river,, we think this result a natural consequence, and from the nature of things very likely to follow. This would do away with the necessity of constantly passing the bridge, and hence remove a great objection generally urged against the erection of similar structures in navigable waters; but we venture to say that the pilot who could not see so plain a monument as a pier 85 feet high and 12 to 18 feet wide at the smallest point, would hardly be able to get a license to navigate rivers where myriads of snags rear their pointed crests for a distance of 3,000 miles at a stretch.

"We propose, however, to show that the bridge is well adapted to the wants of the river marine.

"Let us take the dimensions of some of the largest of the various classes of boats plying on the river."

The report gives the dimensions of a number of steamboats, varying from 235 feet length over all by 61 feet breadth of beam over all, to the *Great Republic*, the largest steamer afloat on the western rivers, which measures 336 feet length over all by 96 feet breadth of beam, and proceeds as follows:

"The principal spans, as determined by the law of Congress, are established at either 500 feet or 350 feet; now, a comparison of the foregoing data with these lengths of span shows that the largest boat on the river would not occupy one-quarter of the width of even the smallest span allowed by law, or with a tow of barges less than one-half the width.

"We think there can hardly be a doubt in the mind of any intelligent man but that the span of 350 feet is abundantly large to enable a free and unrestricted passage at all times.

LETTER OF MR. JULIUS W. ADAMS, CIVIL ENGINEER.

WALLABOUT IMPROVEMENT COMMISSION,
OFFICE OF ENGINEER,
City Hall, Brooklyn, January 7, 1868.

SIR: Your circular of date December 31 is received. In reply, I would beg leave to say, prior to the publication of the proceedings of the Saint Louis convention of engineers (in the deliberation of which I took no part, not having been present), I received from the president of the bridge company, with whom I was personally acquainted, a printed pamphlet of 14 pages, purporting to be the report of the board of engineers, convened at Saint Louis, with the request that if I concurred in the statements therein made, I would *sign* the paper and return it to him, which I did. I subsequently received the published proceedings of the convention, and found that the paper to which I refer constituted a part of it, viz, from page 77 to 90. On page 79, the third paragraph embodies my views as regards the proper length of span to be adopted in this instance.

I should remark that, so far as I know, no form of bridge came up for discussion before the convention, save the horizontal-chord trussed-frame bridge of Mr. Post.

In May of this year, Mr. James B. Eads laid before me the plans, estimates, and calculations for a 500-foot span steel-arch bridge, prepared by him at Saint Louis, with the request that I would give my opinion of its stability, &c.

After due deliberation, I unhesitatingly reported *in favor of the project*, with such modification of detail as occurred to me as desirable, *not affecting the length of span, however*.

I mention this to show that I by no means considered my opinion as having previously been expressed as adverse to spans of 500 feet, or *even greater*, and that Captain Eads so understood my views is shown by the fact of submitting his plans for my approval.

Very respectfully, your obedient servant,

JULIUS W. ADAMS.

Major-General WARREN,
United States Engineers.

LETTER OF MR. DANIEL C. JENNÉ, UNITED STATES CIVIL ENGINEER.

UNITED STATES ENGINEER'S OFFICE,
DES MOINES AND ROCK ISLAND RAPIDS IMPROVEMENTS,
AND ILLINOIS RIVER SURVEY,
Keokuk, Iowa, January 7, 1869.

GENERAL: Your circular of December 21, 1868, was duly received. In reply, would say that I was not present at the convention of civil engineers held at Saint Louis in August, 1867, although my name appears attached to the report of the proceedings.

Therefore I cannot give a definite answer to the question proposed in your circular, but my understanding of the matter is that reference was particularly had to the construction of the bridge across the Mississippi River at Saint Louis, yet it might refer to the general question of bridging important navigable rivers.

Respectfully, your obedient servant,

DANIEL C. JENNÉ,
United States Civil Engineer.

Bvt. Maj. Gen. G. K. WARREN,
Major of Engineers.

LETTERS OF MR. A. ANDERSON, CIVIL ENGINEER.

1.

UNION PACIFIC RAILWAY, EASTERN DIVISION,
OFFICE OF THE GENERAL SUPERINTENDENT,
Lawrence, Kans., January 8, 1869.

MY DEAR SIR: Your letter from Saint Paul came during my absence at the East, as well as your circular.

To the latter I have made the reply inclosed, which seems to cover the points of the case.

I do not see how the resolution adopted by the convention can be reasonably construed to have the meaning attributed by the author of the Cincinnati pamphlet, although it was loosely worded, and its phraseology was objected to by some of the parties present. * * *

Truly, yours,

A. ANDERSON.

Maj. Gen. G. K. WARREN,
United States Engineers, Washington, D. C.

2.

UNION PACIFIC RAILWAY, EASTERN DIVISION,
OFFICE OF THE GENERAL SUPERINTENDENT,
Lawrence, Kans., January 8, 1869.

GENERAL: Your circular is received, asking of me, as a member of the convention of civil engineers, held in Saint Louis in August, 1867, how far it was intended by that convention to decide the question of bridging the great navigable Western rivers.

In reply, I would state that the general question of proper length of spans was not discussed by the convention, or brought before it in any way; neither was the practicability of constructing bridge-spans of 500 feet long or more.

The subject before the convention was, whether it was better to construct a bridge over the Mississippi River at Saint Louis with openings of 500 feet, or to adopt the shorter spans of 350 feet, allowed by the act of Congress authorizing the bridge to be built.

As chief engineer of the bridge company, upon whose invitation the convention assembled, I had recommended constructing the shorter spans, and after an exhaustive examination, embracing all points of commercial as well as engineering interest, the convention unanimously recommended the same.

The phrase in the adopted resolution, "parties in interest," referred only to the bridge company.

I regard the proper width of opening in any bridge over the great rivers as dependent upon the circumstances of each individual case, taking into consideration the wants of navigation and engineering characteristics of the location, and would not hesitate to recommend and construct spans of 500 feet opening, or longer, if the situation made them advisable.

Very respectfully,

A. ANDERSON,
Civil Engineer.

Maj. Gen. G. K. WARREN,
United States Engineers, Washington, D. C.

LETTER OF MR. O. CHANUTE, CIVIL ENGINEER.

ENGINEER'S OFFICE, KANSAS CITY BRIDGE,
Kansas City, Mo., January 8, 1869.

MY DEAR SIR: I am in receipt of your circular under date of December 21, 1868, to members of the Saint Louis bridge convention, inquiring how far I understand their action to have been intended to decide the question of bridging the great navigable Western rivers.

The convention was called, as you are aware, by one of the companies proposing to bridge the Mississippi River at Saint Louis, to examine and report upon the practicability, efficiency, and economy of the plans and estimates previously made by their engineer, A. Anderson, esq., which were submitted to the convention.

As the problem of bridging any of our great rivers would be varied at each point by the circumstances of location, the amount of traffic to be accommodated both on the bridge and the river, and the character and class of the navigation, I think I must express nearly the unanimous sense of the convention in stating that its proceedings were designed to apply merely to the bridging of the Mississippi at Saint Louis.

The law of Congress presented two alternative arrangements over the main channel: either one span of 500 feet or two spans of 350 feet each in the clear. It was understood that a rival company proposed to adopt the 500-foot span, while the plans of superstructure which were submitted to the convention were for beam-trusses, the construction of which, as well as the methods proposed for putting in the foundations, we found to be practical and efficient.

Under these circumstances we did not attempt to suggest any new plans, and recommended the adoption of the alternative, of the two spans 350 feet long, as being the cheapest arrangement, the quickest and safest to erect, and in our judgment sufficient to answer the requirements of navigation at that point. It was understood in discussing the resolutions that it was perfectly practicable to build spans of 500 feet, but that they would be very costly, and that a mistake in plan, material, or workmanship would be far more disastrous than in shorter spans. Several of the engineers present were understood to be prepared to undertake their erection should the circumstances of the case require it and capital be forthcoming for that purpose.

I regret, in common with every member of that convention which I have met since its close, that we allowed resolutions to pass so loosely worded as not to convey clearly our meaning, so that while they could be used by one bridge interest in a manner never contemplated by us, they were justly open to the adverse criticism of another.

Allow me, however, to suggest, in conclusion, that the general question of bridging our great rivers could scarcely be expected to be glanced at, much less (with so progressive a science as engineering) settled, in a four days' session. It seems to me that such a problem may perhaps be best solved by prohibiting certain designs, such as suspension and draw bridges of *any* length, or by any inflexible rule as to spans and heights extending over any considerable part of the course of even a single river; but that it would perhaps be best to let the local requirements and circumstances govern each case. An arrangement which may be found efficient on the Upper Mississippi would probably prove a great nuisance at Saint Louis, and be utterly impracticable at

Memphis or New Orleans, and each bridge should be so arranged that the local navigation can safely pass with ordinary care at all times.

On the other hand, while the requirements of the river commerce should be fully guarded and preserved, it seems wasteful that bridge companies should be required to incur what may be needless expense, and sink capital in providing greater accommodation than is really needed. Long spans, upon any design, are expensive and hazardous; that to require them without the clearest necessity might make the building of bridges so onerous as to deter capital from undertaking works of great public importance.

Very respectfully,

O CHANUTE.

G. K. WARREN, Esq.

LETTER OF MR. W. E. WORTHEN, CIVIL ENGINEER.

63 BLEECKER STREET,
New York, January 9, 1869.

DEAR SIR: In answer to your circular, I did not attend the Saint Louis convention, nor did I understand that by the tacit permission of my name to the report I indorsed 500 feet as the limit of span for a bridge not suspension; in fact, at about the same time I had recommended to an engineer friend that he should adopt the truss and brace for a span of about 750 feet, rather than suspension, as being probably the cheaper and better in the position in which this bridge was to be constructed. In my railway experience I have never had charge of the construction of bridges of over 200 feet span, nor should I adopt any longer than this if cost and position permitted; but if the circumstances of locality and economy of construction and maintenance were in favor of a span of 750 feet, as above recommended by me, I should have no hesitation in adopting it.

I am yours, truly,

W. E. WORTHEN.

Maj. Gen. G. K. WARREN.

LETTER OF MR. E. S. CHESBROUGH, CIVIL ENGINEER.

CHICAGO, *January* 16, 1869.

DEAR SIR: Your circular of December 21 did not reach me until quite recently.

I spent but two days at the Saint Louis convention and did not draw up the report; nevertheless, having signed it, I will not attempt to evade the responsibility attending that act.

In my own mind, the great object of the convention was to advise the bridge company what to do with regard to the adoption of plans. I should be very sorry to say it was impracticable to build a truss-bridge, safe for railway traffic, with a span of 500 feet, or even of 600 feet; but I do think it would be very unwise to attempt either where the circumstances of the case did not make it absolutely necessary. My own experience and observation would lead me to adopt spans of much less length than 500 feet where it could be done without too great a sacrifice in other respects.

The time even the Kuilenburg bridge has been built and tried by such trains as run on American roads has not been sufficient, in my opinion, to pronounce it a safe precedent in cases where such a length of span could be avoided.

Yours, very respectfully,

E. S. CHESBROUGH.

General G. K. WARREN,
United States Army.

LETTER OF MR. FRED. A. CHURCHILL, CIVIL ENGINEER.

SAINT LOUIS, *January* 25, 1869.

DEAR SIR: Your circular dated December 21, 1868, was received in due time, and has had my attention.

I firmly believe that river navigation must in the future give ground to railways more rapidly than ever, and thinking thus, I believe that the most economical bridge structure consistent with the requirements of the location is the best. Therefore, it seems to me that 350 feet is ample for the necessities of the river commerce at this point. A larger span would not, in my opinion, benefit the navigation much, if any, while it would increase very greatly the cost of the bridge.

Of course the peculiar circumstances attending the location of each bridge must weigh greatly with the engineer who has to decide upon the span and other details; and while I am in favor of a medium span at this particular point, being as it were a terminus for the upper and lower river boats, I am in favor of stretching to the utmost limit consistent with safety the spans of all bridges over the great rivers which cross at points intermediate to the large cities along their banks. The character of boats navigating that particular part of the river would also influence me somewhat, so that I am not prepared to adopt any general plan, but would prefer to see the whole question left to a permanent board of engineers, whose business it should be to see that the best interests of the whole country were protected, and no individual caprice suffered to throw obstacles in the way of either river or railway transportation.

I am yours, very respectfully,

FRED. A. CHURCHILL.

G. K. WARREN,
Major Engineers and Brevet Major-General, United States Army.

LETTER OF MR. R. B. MASON, CIVIL ENGINEER.

CHICAGO, *January* 28, 1869.

DEAR SIR: Your circular of December 21, 1868, owing to my absence for the most part of this month, only reached me a few days since.

I was not present, and did not participate in the discussion at the convention of engineers at Saint Louis. I, however, approved generally of their doings; I have never understood from any of those gentlemen that I have talked with since that convention that they considered a 500-feet span impracticable. But a span of 350 feet was considered long enough to meet the requirements of business at that point, and it being cheaper to build with shorter spans, they therefore recommended the shorter spans. This was about the view I took of it. I could not exactly see the necessity of a 500-feet span, and if not necessary, then why build it?

I am not willing to place myself on record that it is impracticable to build a bridge of 500-feet span.

Yours, truly,

R. B. MASON.

G. K. WARREN,
Brevet Major-General.

LETTER OF GENERAL WILLIAM SOOY SMITH, CIVIL ENGINEER.

COUNCIL BLUFFS, IOWA, *February* 8, 1869.

SIR: I have just received your printed circular, dated December 21, 1868, asking how far the convention of engineers assembled to consider the subject of the construction of a railway and highway bridge across the Mississippi River at Saint Louis intended to decide the question of bridging the great navigable western rivers.

As I have no opportunity to confer with other members of the convention, I can only venture to give you my individual impressions.

I think the spirit with which our inquiries were conducted is very well indicated in one of the sentences quoted in your circular from the opening address of our president, viz:

"Although we have been convened at the request of one of the rival companies, yet we are to consider all of the questions bearing on this subject without reference to any particular plan or company."

And while the facts and opinions were elicited by a single case, they have a legitimate application to all similar ones, and so to the general subject of "Bridging the great navigable Western rivers"; though I don't think it was any part of the duty or intention of that convention to extend its inquiries to that general subject.

Perhaps I have now answered all that you intended I should, and yet I cannot refrain from tendering the following considerations upon a subject of so much importance to the engineering profession and to the communities we serve.

I know of but one span (not suspension) that nearly approaches 500 feet in the clear, and that is the long span of the Kuilenburg viaduct, over the river Leck, in Holland, recently completed. This span is 492 feet in the clear, and at American prices for iron and steel would have cost $892,311, three and three-tenths times the cost of the 262½ feet span, and more than the whole 7 spans of 187 feet each of the same viaduct.

The great additional cost of the span proposed (500 feet) will, in my judgment, make the act if passed "practically prohibitory to bridges," except in cases of such necessity as to justify almost any expenditure of money.

I do not think that a 500-feet span is *mechanically impracticable*. The most serious difficulty in the way of the construction and erection of such a span would be experienced in shaping and uniting parts of sufficient dimensions to resist the great strains to which they would be subjected, and in providing falsework on a bottom that may be shifting and unreliable; that could not be depended upon for supporting so costly a superstructure during the time necessarily consumed in putting together in place over *two thousand tons* of iron and steel consisting of so many parts.

The steamboat interest demands that bridges over our navigable rivers shall be placed 50 feet in the clear above high-water surface. This requirement greatly increases the difficulty and expense of falsework to sustain a structure so ponderous and costly. While, therefore, it may be granted that a single span of 500 feet in the clear can be built, it must also be conceded that the construction and erection of such a span over some of the rivers which the public interest requires us to bridge would demand all the resources of the very best mechanical and engineering talent and experience. *It is to be regarded as an extreme to which the engineer should be driven only by an absolute necessity.*

Moreover, the question of safety involved in the adoption of spans of such great length can scarcely be regarded as settled by *a single example so recently furnished.* Of course it is easier to build a short bridge than a long one, the difficulty increasing nearly in proportion to the squares of the distances to be spanned; and whether the limit of safety, with the plans and materials at hand for the use of the engineer, is not reached far within the extreme length of span 500 feet no sufficient experience has yet been had to determine.

The passage of an act making it necessary for the American engineer to exceed with all his bridges over our navigable rivers the greatest length of span yet attained would be viewed with surprise by the engineering profession throughout the world. Legislation requiring us to go beyond the limit of all reliable experience would be unwise, dangerous, and only calculated to prohibit bridges altogether wherever it might apply, except in cases of extreme necessity.

The navigable channels of even our largest Western rivers are rarely 500 feet wide—generally not more than half that width. Then why compel engineers and those interested in the vast trade that seeks transit across our rivers to span sand bars and unnavigable water when such compulsion is so detrimental to these great interests, and involves such nice questions vitally affecting the public safety? Nothing but gross carelessness or criminal intent will bring a steamboat in contact with piers placed from 250 to 350 feet apart in the clear, and parallel with the direction of the current. Otherwise, how can steamboats be kept in the narrow, tortuous channels they now navigate?

It so happens that many of our great navigable rivers lie directly across the lines over which our surplus products must move to reach their best markets. This movement is more important in winter than in summer time; but in winter nearly all of our most important Western rivers are closed by ice. So that even if they ran in the most desirable directions they would not be available at the most favorable season of the year for the transportation of our products. So it happens that the great bulk of the inland carrying-trade is done by railroads, and the interests of the whole producing population of the West are thus vitally affected by any enactment which will so seriously impede the operations of those roads.

As the trade obstructed by the rivers increases, the hinderances thrown in its way unnecessarily by the less important river commerce will become more and more objectionable to the people interested. And have they not a right to demand now that while guarding a minor interest a greater one shall not be sacrificed? It is, of course, of first importance that our great natural channels of inland commerce should be preserved. They are free to all, and can never become the property of powerful combinations and monopolies. But they are not seriously obstructed by an occasional bridge with spans of from 250 feet to 350 feet in the clear, and these in their turn serve to perfect other lines of still greater importance to the great mass of our people.

I think the opinion not only of the Saint Louis convention, but of the great body of engineers in this and all other countries, is adverse to 500 feet spans, except in cases of absolute necessity. They are barely practicable. They may or may not prove permanently safe and reliable, and they are enormously expensive.

Yours, truly,

WM. SOOY SMITH,
Superintending Engineer, Omaha Bridge.

General G. K. WARREN.

LETTER OF MR. J. B. MOULTON, CIVIL ENGINEER.

NORTH MISSOURI RAILWAY COMPANY,
CHIEF ENGINEER'S OFFICE,
Saint Louis, February 10, 1869.

DEAR SIR: Your printed circular dated at Saint Paul, Minn., addressed to the members of the convention of civil engineers held in Saint Louis, Mo., in August, 1867, to consider the subject of a railway and highway bridge across the Mississippi River, has been read by me with much interest.

The whole tone of your letter goes to show that your great desire is to collect correct information, to the end of doing the greatest good you can to the railway interests of the West, and at the same time to preserve the integrity of navigation on the Ohio, Mississippi, and Missouri Rivers. These rivers are the great competitors of Western railways as carriers, and the unobstructed, free navigation of which is a matter of great importance to the country.

It is equally important, however, that the railway interest be not overburdened, or be forced to greater outlay of money in building bridges than is necessary to protect the boating interests. Believing that you wished to get the opinions of practical men as well as scientific, I addressed a note to Col. C. Shaler Smith, of the firm of Smith & Latrobe, Baltimore, who combines both these qualities, requesting him to give his views of spans which can be adopted over Western navigable rivers without injuring railroad interests too much by great outlays, which I herewith inclose.

I do not fully agree with the views expressed in it as to the necessity of the very long spans mentioned. For while I admit the possibility of constructing long spans, it seems to me that Congress would not be justified in going beyond the requirements of Western navigation, and I am one of those who believe that it does not require spans reaching beyond 350 feet. Indeed it seems to me that spans of 300 feet in the clear will accommodate all possible contingencies, except perhaps when made directly opposite our largest cities, where boats of the different classes of tonnage exchange freight. Colonel Smith admits, and in this I agree with him, that the cost of superstructure is nearly as the square of the span; which will make a span of 500 feet cost within 25 per cent. of three times as much as a span of 300 feet. This is more than most Western railways can spare to build bridges over the rivers named.

Draw-bridges, built and proposed in some instances, have been and will be built by independent companies, because railroad companies are too poor; these companies charge toll, which nets a profit, and will continue to do so, at the cost of the shipper, no doubt, for a long time.

Owners of railroads will contend that they should not be required to build bridges beyond a span which will not obstruct navigation. Steamboat-owners will contend for long spans, as it is manifestly their interest to keep back the bridges as long as they can, while railroad owners for a parallel reason will contend for the cheapest bridge. A proper discussion will bring the minds of Congress to see the propriety of taking a mean that will do justice to both sides. Pilots will be slow to testify that 300 feet is not enough; a contrary opinion would be refuted by the fact that on every trip at ordinary stages of water they are compelled to steer their boats through channels much less than 300 feet wide, which is often done at night with no moon in sight. It is for the interest of all railroad companies or bridge companies to build high bridges, and they ought to be compelled to do so, as a safeguard against accidents to both bridges and steamboats. Besides, a river carrying almost the whole year an immense amount of sand and silt is likely, and does, in fact, alter its channels, which, with a draw-bridge, will give trouble, while under high bridges it will be avoided.

This will apply with much force to these three rivers, except to the Mississippi above the mouth of the Missouri. Another reason why high bridges should be adopted is that the requisite spans are not attainable with draws.

I am aware that I have not yet answered your question asked in the printed circular, nor is it necessary if what I have said is noticed.

The convention was, as you suppose, called in the interest of the rival bridge company. You mention a fact I did not happen to know when I accepted the call to attend, and many of the civil engineers whose names are appended to the report did not attend, although I think they all saw the report and signed it before the printed form had much circulation. I did not have much to do in the matter, except to contribute to the "Report on the regimen of the river near Saint Louis and Saint Charles." The gentlemen composing that convention with whom I became acquained, many of them for the first time, while in Saint Louis, are engineers much older and better skilled in bridge-building than I am, and to whose opinions I defer. My opinions as to spans best adapted to bridges on the Ohio, Mississippi, and Missouri Rivers are contained in this communication.

Under different circumstances I should have much preferred to have been silent; as it is, I write with a full knowledge of the inadequacy of my experience and judgment in treating a subject properly so vital to the commercial industry of the West.

Your obedient servant,

J. B. MOULTON

General G. K. WARREN, *U. S. A.*

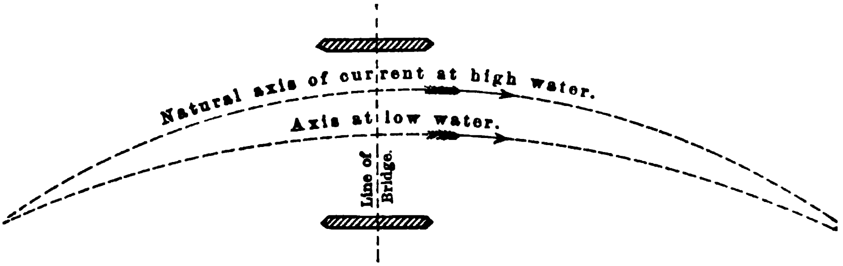
LETTER OF GENERAL C. SHALER SMITH, CIVIL ENGINEER.

NORTH MISSOURI RAILWAY,
ENGINEER'S OFFICE SAINT CHARLES BRIDGE,
Saint Charles, Mo., January 23, 1869.

DEAR COLONEL: In reference to the letter of General Warren received from you, I would say that in regard to the proper length of spans on navigable streams, I have come to the following conclusions:

First That the location should be such that there is a clear distance both above and below the bridge of two and a half boat-lengths (longest boat in the trade) of straight current, and that where this is the case the span should be sufficient to allow the longest boat on the river to float through sidewise, and the longest and broadest tow-fleet to go through at an angle of 30° with the line of the current. The location of the piers, in this case, should be such that the *natural axis* of the current is through the middle of the span, without reference to the deepest water. Where this is attended to, the normal action of the current will carry an unmanageable boat or tow through without danger.

Where the location cannot be made over a straight current, the principles which should govern are these: Ascertain the distance in the line of the bridge between the axis of the current at the lowest navigable stage, and the same at the highest water, and *add this distance* to the length of span previously determined for a straight current. This will carry a boat through, as before, by the natural action of the current alone, whether the river be low or high. You can judge of the principle from the following sketch:



I have made a good many experiments on the lee-way made by boats in turning a bend and from wind, but I find the foregoing principles come more near to covering all possible points than any plan I have yet seen or thought of. In applying this to practice on the Missouri River, we have, at the Saint Charles bridge, 1,000 feet of straight current above the bridge and 1,800 feet below. From the regimen and character of the river, towboats will never become profitable on it; so the longest boat fixes the span; this is 285 feet; and allowing 15 feet at each end of the boat for clearance, we have 315 feet as the proper span.

The arrangements here suit the river interests so well, that not only have they not attempted to enjoin us, but a number of pilots have voluntarily communicated with me for the purpose of expressing their entire satisfaction.

On the Mississippi and Ohio Rivers the longest tow-fleet would fix the spans. This would be 7 barges wide and 3 barges long, or a rectangle of 480 by 182 feet. This, at an angle of 30°, will require 400 feet net, and 430 feet with the proper clearances. This for a span over a straight current. In the curved current in the bend just at Saint Charles, where the varying axis of the current equals, I should think, the variations likely to take place at any point on the Ohio or Mississippi Rivers which would be selected for a bridge, the distance between the high and low water axis is 80 feet; add this to 430 feet, and we have 510 feet as the widest span which would probably be required on the rivers in question.

In relation to the practicability of these long spans, this is simply a matter of cost. Any one of the four or five of the best forms of truss in use in this country can be extended to 700 feet span in iron or 1,000 feet in steel, without either difficulty or danger. One of our firm has just successfully extended the common Howe truss, without an arch but with a wrought-iron lower chord, to 300 feet span, and this without exposing the wood at any point to more than 1,000 pounds per square inch, with the truss fully loaded. When this can be done with a material like wood, it is easy to see the extended limit which can be reached with such a material as steel, which is good for 25,000 pounds per inch.

Up to within the limits I have given, the cost of a truss is very nearly in proportion to the square of the span, the girders of the arch and bowstring types, however, increasing in relative economy with the truss-girders proper, as the spans are lengthened.

Yours, very truly,

C. SHALER SMITH,
Chief Engineer Saint Charles Bridge.

Col. J. B. MOULTON,
Chief Engineer North Missouri Railroad.

[Indorsement.]

Respectfully referred to General G. K. Warren, U. S. A.

LETTER OF MR. W. W. EVANS, CIVIL ENGINEER.

NEW YORK,
47 *Exchange Place, February* 15, 1869.

GENERAL: I am in receipt of your circular-letter in reference to the report of the convention held in Saint Louis in August, 1867, to consider the subject of a railway and highway bridge across the Mississippi River at Saint Louis.

In answer, I would say that, although my name appears as one of the convention, I was not present, and did not see the report until after it appeared in pamphlet form.

The president of that convention was my chief for a number of years, and having always had the most exalted opinion of his engineering ability, I told him I would sign the report, and would sign anything he would put his name to. In this way my name became attached to the report.

I beg now to say, in reference to the questions asked, that I fully believe in the practicability of building girder-bridges of 500 feet clear span, but I do not believe in the propriety of them in any case or under any circumstances; but I do believe in the propriety, the economy, the reliability, and the usefulness of bridges of suspension for railway and highway purposes of spans ranging from 500 to 3,000 feet.

Why the law should have been framed to exclude the suspension principle is, to me, inexplicable, when we have in existence a railway bridge of much greater span which has given satisfaction.

That bridges on the girder principle of 500 feet span can be built there is now no longer reason to doubt, with the knowledge we have of the Britannia bridge, 459 feet 3 inches span, and the bridge just constructed over the Leck at Kuilenburg, in Holland, of 492 feet span, and another over the Moldau at Prague, in Austria, of the same span. But I would ask, what engineer is there in the United States bold enough to recommend such bridges for construction here, when he has staring him in the face the figures 2,123 as the tons of iron and steel used in the construction of one span of 492 feet, and the figures 3,000 as representing the tons of iron used in one span of the Britannia bridge, of less than 460 feet, and then compare these figures with the 400 tons of iron and less than 600 tons of wood used by Roebling in the construction of the Niagara suspension-bridge of over 800 feet span. I am fully convinced, after years of investigation, that bridges of 500 feet span of iron and steel for railway purposes, having no curved lines in any of the chief members, and having as much rigidity as the Britannia bridge, can be built, and successfully built, on the truss suspension principle with much less than 700 tons of metal. Fink's patent suspension truss-bridge, as now built by an eminent engineering firm of Baltimore, and very extensively used throughout the country in spans of 250 to 400 feet, combines many of the features required in a Roebling bridge. This plan may, in my opinion, be improved for very long spans, by introducing a plan for keeping the main suspension members in straight lines, by auxiliary chains, as supporters of the sag, which would naturally take place. This feature in bridge-building will, before long, be understood, appreciated, and used for railway bridges of very long spans. I see no good reason why railway bridges of 1,000, 1,500, or even 3,000 feet span should not be built, when occasion and circumstances call for them. But spans of these dimensions evidently cannot be built where the chief members are arches, depending on compression for strength. Bars, or beams, or columns, beyond a certain length, cannot be depended on for strength, without much lateral bracing and propping on every side, and even then no man can tell when and where buckling and doubling up will take place, while a bar or chain of iron or steel, or cable-wire, has a known strength, no matter what the length, and can be relied upon.

The suspension principle is fully understood and appreciated by the leading engineers of the United States; so it is a folly for legislators and others, at the present day, to ignore its merits.

Mr. Roebling deserves much praise and lasting honors for the boldness exhibited in design and the skill developed in execution in railway bridges of suspension, and that, too, after the matter had been discussed and condemned by the Institution of Engineers in England.

It is shown by actual results that the deflection of the Niagara suspension-bridge, which has a span of 821 feet 4 inches, is about the same in proportion to the span as that of the Britannia bridge, a rigid iron-plate girder, of 459 feet 3 inches, while each are loaded with 300 tons.

When the Niagara suspension railway bridge became a fixed fact, European engineers made it the subject of much discussion. Many of the routine engineers, those that had been brought up in a groove, could not believe in it, and do not believe in it to this day; but one among them, a well-known writer on the strength of materials, Peter W. Barlow, packed his valise, came to this country on purpose to look at this wonder after it had been in existence over five and a half years. It may be interesting to quote some of his opinions and conclusions, taken from a pamphlet published on his return to England. On page 6 he says: "The suspension principle, if correctly carried out, is the safest as well as the most economical application of iron to railway structures." On page 18: "Oxidation is slow where every point can be got at and painted. Tube-bridges, with cells difficult to be got at, will be more liable to loss of strength from this cause." Page 19: "The durability of the Niagara bridge cables will not be less than the masonry of which the towers are built." Page 22: He shows the ratio of strength to strain by weight of bridge to be, in the Niagara bridge, 6.5 to 1, and in the Britannia bridge, 3.4 to 1; the Conway bridge 3.8 to 1, and the Saltash bridge, 5 to 1. Page 30, he says: "The Niagara bridge is the safest and most durable bridge of large span that has been constructed. Had wrought iron been used for trussing, the total weight would not have exceeded 800 tons, the deflection of the wave reduced to 2 inches, and the strain on the cables to one-eighth of their ultimate strength. It is clear, therefore, that 820 feet is not the limit of the opening that can be crossed by this principle, but that spans as high as 3,000 or 5,000 feet can be carried out for railways without exceeding the safe limit of strain on the wire cables, and at a cost which would render remunerative connections and communications which are now considered impracticable." Mr. Barlow then goes on to estimate the dimensions, strength, and cost of a suspension bridge of 3,000 feet span which he proposes to build between Liverpool and Birkenhead.

From the foregoing notes and opinions of one of the first of English engineers, together with what we know and can see for ourselves, who is there that can doubt, who is there bold enough to ignore the strength, the iconomy, the safety, the durability, and the good merit of the suspension principle for railway-bridges of great span? I am in the belief that a very large portion of the educated people of this country are ignorant of what can be done with steel, and how differently it will act under certain circumstances of extension and compression. It is common among engineers to demonstrate facts and show differences by caricatures. Let us take this method to show what steel can do in tension, and what it *cannot* do in compression. Suppose steel wire to have a tensile strength of more than 150,000 pounds to the square inch; also, that 1-inch cube will have a compressive strength of more than 150,000 pounds, and there is plenty of steel that can be found that will exceed these figures. Now, let us suppose that 4 cubic inches will weigh one pound, which, in round numbers, is not far from the truth, there will be 50,000 feet of solid steel wire (one square inch area) in the 150,000 pounds, and there will be tensile strength enough in it, if in one piece, to hold itself, if suspended from a point 50,000 feet above the earth, and hanging in a straight line. Then, suppose you rest the lower end on a well-prepared foundation, and let go of the upper end, what would become of the 50,000 feet when you come to depend on its compressive strength? Is it not clear that it will double up into a thousand folds and twists, and come down to mother earth with a rush? and yet the first cubic inch at the bottom was prepared to hold the whole of it without crushing. Suppose we take 3,000 feet of this 1-inch square solid cable of steel wire and hang it on a hook 3,000 feet above the earth, what will it hold? Why, it will hold itself, which will weigh 9,000 pounds, and a ball of 141,000 pounds, which is the balance of 150,000. But what will become of the 3,000 feet if compression is depended on, to say nothing of the 141,000-pound ball? Why, it will come down as before. What will become of 10 feet of this cable, of 5, or even 2 feet of it, if it is stood up, and the 141,000-pound ball, or the tenth part of it, was placed on top? Why, it would buckle, and the ball would have a tumble.

This, general, is not a very scientific way of writing, but it is one every person can understand, and I only write it in this caricatured light to show the difference that exists between compression and tension in long-span bridges, where economy and reliability are considered, and where the engineer is performing his chief function of making the most out of the least.

Captain Eads is a bold man to design an arched bridge with spans of 500 feet, and will deserve credit for his boldness and nerve if successful, but I doubt if he will deserve or receive much credit for spending two or three times the amount the circumstances called for.

I am, general, your obedient servant,

W. W. EVANS.

ANNUAL REPORT OF CAPTAIN EADS FOR 1869.*

The next report of Captain Eads, chief engineer, made to the president and directors, that I have seen is dated September 1, 1869. It is contained in nineteen pages, 8vo. He had visited Europe in the preceding winter, and witnessed the *plenum pneumatic* process of sinking piers, which he thought so favorably of that he proposed to adopt it in sinking those of this bridge to the bed-rock. Much work of preparation had already been done, but the masonry building had been confined to the Saint Louis abutment and the piers of that approach. Mr. W. Milnor Roberts had been appointed associate chief engineer.

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*Illinois and St. Louis Bridge Company. | Report | of the | Chief Engineer, | September, 1869. | St. Louis, | Missouri Democrat book and job printing house, | 1869.

ANNUAL REPORT OF CAPTAIN EADS FOR 1870.*

This report occupies, with an appendix, 55 pages, 8vo, and is accompanied by a drawing showing the bridge-spans as revised, and the rock stratum on which the piers were to rest. There are besides four plates showing construction works and machinery, caissons, arrangements of air-locks, &c. The final designs were now essentially completed, and the work well under way. The account of the methods employed and the experience developed makes it a very interesting and valuable report. The final design for the ribbed arches makes the steel tubes 18 inches in diameter, placed 12 feet apart from centers and connected by triangular bracing. There are four such in each span, and the arc is the arc of a circle. The versed sine of the center span is 47.5 feet and the crown is 55 feet above the city directrix, so that the springing line is 7½ feet above the city directrix. The springing line of the side spans next the abutments are 18 inches lower, or 6 feet above the city directrix. The highest known flood, that of 1844, was 7.58 feet above the city directrix, so that it is barely possible that the extreme floods can reach the arches at the springing lines. The versed sine of the side arches is 43 feet, so that the crowns are 50.5 feet above the city directrix.

The great objection made to this form of structure by the navigation interests is in its allowing so little width of full headway. The report of 1870 is the last one I have seen from the engineer of the bridge.

REPORTS OF A BOARD OF ARMY ENGINEERS.

When in the summer of 1873 the near approach of the completion of the arches of the span next to Saint Louis brought to the steamboatmen's eyes the exact nature of the effect the bridge would have upon navigation, the steamboatmen at Saint Louis became much disturbed and made application to the Secretary of War to have the nature of the impending obstruction investigated and reported upon by a Board of Engineers. This Board, of which General J. H. Simpson was president, was convened by special orders dated August 20, 1873, which directed an examination to be made, and report whether the bridge will prove a serious obstruction to the navigation of the river, and, if so, in what manner its construction can be modified.

The Board reported, September 11, that it would be a serious obstruction, and could devise no remedy, if the bridge was allowed to stand, except to build a canal around it on the Illinois side and place a drawbridge over the canal. This report was replied to by Captain Eads, and charges of unfair treatment were made by the bridge company's agents. A replication was made by the Board in a supplemental report dated January 31, 1874. The whole was printed as House Ex. Doc. No. 194, Forty-third Congress, first session, comprising 45 pages, 8vo. It was reprinted in the Annual Report of the Chief of Engineers for 1874, pp. 636–680, and contains a good deal of useful information. I will caution any one from being misled by the last three horizontal rows of figures in Table H. The last two should be stricken out. The result is properly stated in Chapter III of the present report.

The bridge was completed and opened for travel in July, 1874.

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* Illinois and St. Louis Bridge Company. | Report | of the | Chief Engineer, | October, 1870. | St. Louis, | George Knapp & Co., printers and binders, | 1870.

OTHER SOURCES OF INFORMATION CONCERNING THE SAINT LOUIS BRIDGE.

The Transactions of the American Society of Civil Engineers contains several papers:

(1) In volume II, pp. 135–139, paper No. XLVII, is "A description of the proposed plan for erecting the superstructure of the Illinois and Saint Louis bridge," accompanied by an illustration by Walter Katté, C. E., read June 6, 1872.

(2) In volume III, pp. 195–215, paper No. XCVIII, with six plates of illustrations, "UPRIGHT ARCHED BRIDGES," by James B. Eads, civil engineer, read June 10, 1874.

This paper presented a different form of bridge from that at Saint Louis, to remedy some of the disadvantages of the system adopted for the superstructure of that bridge. He aimed "to show that upright arched bridges can be more economically constructed than is possible by any other method whatever, no matter what length of span may be required." This proposition was contested in a discussion which followed the reading by C. Macdonald, p. 215; A. Welch, J. D. Steele, and W. S. Pope, p. 216; T. C. Clarke, p. 222; L. Nickerson, p. 224; S. H. Shreve, pp. 227–232; S. Whipple, pp. 235–238.

Mr. Shreve continued the discussion, volume III, pp. 285–286, and submitted a "comparative estimate of the amount of iron in the trapezoidal truss and in the upright arch, reduced to like conditions." Mr. Clemens Herschell submitted additional remarks on the subject of upright arched bridges, pp. 286–288. Mr. Eads replied to the criticisms made, pp. 319–334.

(3) In volume III, pp. 239–254, paper XCIX. *Notes* on the erection of the Illinois and Saint Louis bridge, presented June 10, 1874, by Theodore Cooper, with sketches to illustrate. This paper contains some accurate information about the joining of the parts of the steel tubes not given elsewhere.

(4) In volume IV, *Upright bridges discussed.* S. Whipple, pp. 81–85; S. H. Shreve, pp. 162–173; James B. Eads, pp. 174–184; S. Whipple, pp. 201–203.

ROEBLING'S DESIGNS FOR BRIDGES AT SAINT LOUIS.

Detailed plans for three different bridges at this place were elaborated by Mr. John A. Roebling, civil engineer. They were to accommodate two railway-tracks on one floor, and a wagon-way for vehicles and street-cars to pass both ways, and with two sidewalks above. The headway to be allowed steamboats was 90 feet above low-water, or about 57 feet above the city directrix. Two of the designs were for a parabolic truss, and one for a pure suspension bridge. The work also contains complete designs for a parabolic truss-bridge for the Ohio River with one span of 500 feet and two adjoining ones of 300 feet; also plans for various spans 400 feet and less.

The designs were completely worked out, and were about finished for publication when he met with the accident while surveying the site of the East River bridge, which caused his death. The work was afterward published and elaborately illustrated by his heirs, forming a folio of 48 pages, including a preface by his son, Washington A. Roebling, civil engineer. Short-span bridges occupy two additional pages, and there are some 20 pages of tabular statements of strains, costs of steel trusses, &c. There are 13 beautifully-executed steel plates giving general and detailed forms and dimensions of parts. The frontispiece is an excellent likeness of this renowned engineer. The work is published by D. Van Nostrand, 23 Murray street and 27 Warren street, New York, 1869. The title-page is, "Long and Short Span Railway Bridges, by John A. Roebling, Civil Engineer."

"The greatest economy in bridging can only be obtained by a judicious application of the parabolic truss."

RECENT DECISIONS OF THE UNITED STATES SUPREME COURT FOR DAMAGES SUSTAINED AT THE SAINT PAUL RAILWAY DRAW-BRIDGE.

The following decisions in the cases of the *Lady Pike* and the *Mollie Mohler* have much interest. This bridge is just at the upper limit of the field of investigation assigned to me. (See Diagram 5.) The bridge, as far as I know, has never been declared a post-route by Congress. It is authorized by the legislature of the State of Minnesota, in which both banks of the river are situated, and is all within the jurisdiction of one United States district court; so that it seems probable that the owners of the steamboats could have brought suits for damages against the bridge-owners, but I am not aware that they ever did. The great danger the piers of the bridge occasioned to navigation is so fully set forth by the Supreme Court that it seems hardly possible that any one would have been allowed to so obstruct a navigable stream. There was nothing left the navigator but to stop or to undertake risks for which he had to pay all the damages. The case of the *Lady Pike* was decided at the October term in 1874 (Wallace Reports, vol. 21, pp. 1 to 17), from which the following is extracted:

Appeal from the circuit court for the eastern district of Wisconsin.

The Germania Insurance Company had insured a cargo of wheat laden on a barge at Shakopee, on the Minnesota River, and about to be towed by the steamer Lady Pike down the River to its junction with the Mississippi, thence down the Mississippi to Savannah, Ill., *unavoidable dangers of the river* * * * only excepted. The cargo was laden on the barge and the transportation of it begun. In the course of the voyage, however, the barge was wrecked. The insurance company paid the loss, and, alleging that the barge had been wrecked owing to the negligent manner in which the steamer had towed her, filed a libel against the steamer to recover what had been paid for the loss. The owners of the steamer set up that the wrecking had been caused by an "unavoidable danger of the river," and was therefore within the dangers from which they had excepted themselves. And whether the catastrophe was caused by an "unavoidable danger of the river" or by the steamer's negligence was the question.

The case was thus:

In April, 1866, there stood in the Mississippi River, just above Saint Paul, certain piers of a bridge then in process of construction, beginning on the west side[*] of the river, and numbered 1, 2, 3, 4, and 5, pier No. 3 (a turn-table pier) being so far unfinished as that, *when the river was high*, barges like that on which this wheat was laden could pass in safety over it, though when the water was low they could not. In low-water the pier was exposed. Owing to a gravel-point on the west side of the river, which projected itself into the stream and against which the water struck, the current, in high-water especially, rebounded and ran diagonally across the piers toward the east shore, so that "a boat in going between piers No. 3 and No. 4 would drift from 4 to 6 feet toward pier No. 4."[†] Hills bounded each side of the river for many miles along its course, or occasional openings or "coolies,"[‡] as the navigators call them, through which wind blows, that at other places in the river are arrested by the hills.

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[*] "West or right bank" is here more properly the *southeast* side, as the river flows in this part northeast.—G. K. W.

[†] The United States laws authorizing bridges require that the piers shall be parallel to the current of the river. These bridge-piers would not have been in accordance with those laws.

[‡] Properly *coulé*, a name given by the Canadians to the ravine made by a side rivulet or run.

One of the openings or coolies existed on the west side of the river, opposite to these piers. The space between piers No. 3 and No. 4, when No. 3 was above water, was about 116 feet; that between No. 2 and No. 4* was 264 feet; that between No. 4 and No. 5 was 151 feet. The main part of the channel was between No. 3 and No. 4; there was the draw of the bridge, and it was between those piers that boats and tows going down the river, and sufficiently narrow to pass through in safety, usually went. The passage between No. 4 and No. 5 was, at one time, obstructed by a sunken barge, but this was after the time of the transit now under consideration. That passage—the passage between No. 4 and No. 5—at this time was clear and of sufficient depth for the *Lady Pike* and her tow to have passed in safety.

In this state of things it was, the rivers Minnesota and Mississippi being at the time full with spring waters, that the Lady Pike, a stern-wheel steamer, "a high boat which would catch a good deal of wind on her sides," set off from her moorings with three barges in tow, laden with 600 tons of wheat, a tow which was to be styled a heavy tow. One barge, larger than the other two, was lashed on one side, and the remaining two upon the other.

The width of all the vessels, steamer and barges, when close alongside each other, was 105 feet. They were all stanch and the steamer abundantly supplied with men, including two master-mariners and two pilots. Scudding clouds prevented the day from being absolutely clear, and "puffs, gusts, or squalls of wind" came up from time to time. These had "bothered" the pilot nowhere, however, in a way worth mentioning, and the vessel had had no trouble except a little in going between the piers of another bridge higher up the stream, between which, however, they had got safely.

On approaching the piers just above Saint Paul, of which we are now principally speaking, the vessel being under a headway of about 7 miles an hour†—no squalls *then* blowing and no "slow bell" having been sounded—the pilot of the steamer, judging by his eye, and thus judging, being under the impression that he could do so safely, attempted to run his steamer and its tow between pier No. 3 and No. 4. He was apparently ignorant of the exact width of his steamer and its tow, ignorant also of the exact distance between the piers, and ignorant, besides, of the fact that in the then height of the water he could have run *over* pier No. 3, and ignorant in addition, or not appreciative of the diagonal effect of the current as it set in high-water between the piers. The result was that one of the barges struck pier No. 4 and was wrecked.

The captain and other officers of the steamer swore that *just as they were going through the piers* a squall arose and drove the barge against the pier; that the accident arose through no negligence, and was an unavoidable danger of the river.

The district court held that this was the true view of the case, and dismissed the libel.

The circuit court affirmed the decree, and the case was now brought here by the insurance companies for review.

Arguments on both sides were made, and Mr. Justice Clifford delivered the opinion of the court, from which the following extracts were made, relating especially to the navigation and the bridge:

* * * * * *

They, the steamer and barges, were all arranged abreast, the larger barge being lashed to the starboard side of the steamer, and the smaller of the other two being lashed to the port side of the steamer between the steamer and the starboard side of the barge containing the wheat which is the subject of litigation. Different estimates are made by witnesses as to the width of the whole craft as arranged, but the evidence, taken as a whole, convinces the court that the steamer and the three barges combined, including the guards of the steamer and the planking of the barges, could not have been less than 105 feet, even if they were all closely lashed together, which is highly improbable. Lashed as they were, broadside to broadside, of course the stem of the steamer was much in advance of some or all of the respective stems of the barges, as she exceeded in length even the largest barge more than 50 feet.‡

The opinion of the court continues to narrate the proceedings of the case, stating that the decision of the district court was against the libellants of the boat, and that the circuit court had entered a decree affirming it.

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* When No. 3 was below the water.

† This speed must have included the velocity of the current.—G. K. W.

‡ It is highly improbable that the tow was made up in the position, with regard to the bows of the steamer and barges, which the court inferred. The practice with navigation is to make the barges project in front of the steamer, so as to facilitate steerage and control over them. It would be proof of the captain's incompetency if he neglected this advantageous custom and took the arrangement accepted by the court.—G. K. W.

Whereupon the libellants appealed to this court.

Errors assigned here are in substance and effect as follows:

1. That the steamer and barge were not properly manned, nor were they fit for the voyage, as neither the master nor pilots had either the requisite knowledge of the vessel under their command or of the dangers and difficulties of the navigation which they had to meet in the course of the trip down the river.

2. That the pilot improperly endeavored to steer the craft midway between piers Nos. 3 and 4, when he ought to have known that the latter pier was so far under water that the craft might have safely passed over it, as was usually done in times of high water, by which improper and unnecessary act the barge containing the wheat was brought within 5¼ or 6 feet of the pier which she struck; whereas, if the pilot had steered the craft farther to the westward and passed over that pier, as he should have done at that stage of the water, the distance to the piers on either side of the craft would have been so great as to have avoided all danger of collision.

3. That the craft might have been navigated in safety between piers Nos. 4 and 5, which were 151 feet apart, showing that the craft might have been navigated through that pass leaving a space on either side of 23 feet, which is manifestly too great to have been overcome by the alleged gust of wind.

4. That the speed of the steamer with the barges in tow in passing between the piers was improper and unwarrantable, and was the efficient cause of the disaster and loss.

5. That it was the course of the current which was unknown to the pilot that drove the craft to the leeward, and not the wind, as alleged in the answer, and the libellants allege that the pilot, if he had had proper knowledge of the navigation, might have prevented that movement of the craft by the exercise of due skill in steering.

1. Applied exclusively to the number of the steamer's company, the complaint contained in the first assignment of errors would not be well founded, as the crew was sufficient in number, and the proofs show that the steamer had on board two pilots and two master mariners, but the gravamen of the complaint is that neither the master in charge of the deck nor the pilot had any sufficient knowledge of the craft under their command, nor of the dangers of the navigation in passing down the river in such a steamer with three such barges in tow arranged in the manner before described.

Proof of the most satisfactory character is exhibited that they (the master and pilot) did not even know the width of the craft, as the same was arranged, nor the actual distance between the piers where the disaster occurred. On the contrary, it appears that they both overestimated the width of the space between the piers, and underestimated the width of the tow, including the steamer, as they were arranged abreast, the distance between the two first-named piers not exceeding 116 feet, and the width of the whole craft being at least 105 feet. Nor does the fact that the pier on the starboard side was so far under water that the craft might have passed over it palliate the rashness of the act, as the evidence shows that both the master and the pilot were ignorant of the fact, and, as they approached the place of danger they put the steamer upon a course to cause the whole craft to pass midway between those two piers, which brought the port side of the barge containing the wheat within 5 or 6 feet of the pier on that side, which was not submerged in the water.

2. Attempt is made to excuse the master and pilot for endeavoring to pass midway between those piers upon the ground that it would be safe to pass over the pier on the starboard side, but the sufficiency of that excuse cannot be admitted for two reasons: (1) because they ought to have known both the dangers and the facilities of navigation before undertaking the responsible duties in which they were engaged; (2) because it was their duty, if they believed that the pass in question was restricted to the distance between the two piers, to have taken the other pass, which the evidence shows has the width of 151 feet.*

Opposed to that is the suggestion that the wider passage was obstructed by a sunken barge, but the evidence satisfies the court that the alleged obstruction did not exist at that time, and that the disaster that caused the barge to sink occurred at a later period.

3. Unobstructed as the wider passage was, it was plainly a rash act to attempt to pass down the narrower passage on a course which brought the port side of the barge containing the wheat within 5¼ or 6 feet of the pier on that side, which act can only be accounted for upon the ground of negligence and inexcusable ignorance of the dangers and facilities of the navigation, as it was evidently a hazardous experiment to attempt to pass between those piers if the craft could not pass over the pier on the starboard side, and

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* It must be borne in mind that none of the spans of the bridge were yet put up. If they had been, then the passage run by the *Lady Pike* would have been the only available one, and not the opening of 151 feet not yet spanned.—G. K. W.

it is equally clear that it would have been safe to have steered between the piers forming the wider passage, which it seems never occurred to the master or pilot.

4. Even if such an attempt could be justified at all on a windy day when the water was high, it is quite clear that neither skill nor good judgment was exercised in setting the course of the craft before passing between the piers.

Beyond all doubt some allowance, though the margin was small, should have been made for the leeway of the craft, as the evidence is convincing that the course of the current at high-water tends somewhat to force the craft toward the pier on the port side. Besides, they had met with some difficulty previously during the trip that day at the bridge higher up the river, and therefore were forewarned that a like difficulty might again occur.

Ignorance of the danger before them is no sufficient excuse, as the owner appoints the master and is bound to select one of competent skill and knowledge to transport goods and merchandise shipped on board in safety, which necessarily imposes the obligation to employ a master-mariner who knows enough about the route to avoid the known obstructions and to choose the most feasible track for his route. Knowledge of the kind in river navigation is peculiarly essential, as the current frequently shifts from one side toward the other, and the track of navigation is often obstructed by snags, sand-bars, and shoals, which no degree of skill would enable the mariner or pilot to avoid without a prior knowledge of their existence.

Cross-currents between the piers of the bridges, which span the river somewhat diagonally, are not infrequent, and as they are not always fully appreciable to the casual observer it is important that the master-mariners should know of their existence and something of their force in order that they may be able to steer their steamer or other vessel properly through such a passage. Neither the master nor pilot in this case knew that there was any such cross-current between these piers, and consequently took no precaution to guard against its influence.

Carriers of merchandise by water seeking general employment are to be regarded as common carriers, and like common carriers by land, in the absence of any legislative provision prescribing a different rule, are in general to be held responsible as insurers, and consequently are liable in all events and for every loss or damage to the merchandise, unless it happened by the act of God, the public enemy, or by the act of the shipper, or by some other cause or accident, without any fault or negligence on their part, as expressly excepted in the bill of lading or contract of shipment.

Standard authorities show that the first duty of the carrier, and one that is *implied by law*, is to provide a seaworthy vessel, well furnished with proper motive power and furniture necessary for the voyage. Necessary equipment is as requisite as that the hull of the vessel should be stanch and strong, and she must also be provided with a crew adequate in number and competent for their duty with reference to all the exigencies of the intended route, and with a competent and skillful master of sound judgment and discretion and with sufficient knowledge of the route and experience in navigation to be able to perform in a proper manner all the ordinary duties required of him as master of the vessel.

Owners of vessels employed as such carriers must see to it that the master is qualified for his situation, as they are responsible for his want of skill and knowledge in that behalf, and for his negligence and bad seamanship. In the absence of any special agreement to the contrary, or exception in the bill of lading or contract of shipment, his duty extends to all that relates to the loading, as well as the safe-keeping, due transportation, and right delivery of the goods, and for the faithful performance of all those duties the ship is liable as well as the master and owners.

5. Differences of opinion may arise as to the merits of the fourth assignment of errors, and inasmuch as enough is alleged in those which precede and follow it to show that the decree of the circuit court must be reversed, the court here does not find it necessary to determine the question whether the speed of the steamer, in view of the conflicting testimony upon the subject, was or was not greater than the exigencies of the impending peril would justify.

6. Nor is it necessary to express any decided opinion whether the fifth assignment of error is or is not supported by the evidence exhibited in the case, but it is deemed proper to say that there is much reason to conclude that it was the course of the current that forced the craft to the leeward and not the gust of wind, as was supposed by those in charge of the deck of the steamer at the time the barge was sunk. Enough appears to show that the bridge there does not span the river directly across the current and that the tendency of the current is to force the vessel passing down the river to the leeward; and the evidence is full to the point that neither the master nor the pilot had any knowledge that they would have to encounter any such difficulty in attempting to effect the passage between those piers. Support to that proposition is found in the fact that they did not think it necessary to adopt any precaution to prevent such a disaster, except to see that the craft headed midway between the piers of the narrow passage and to give the steamer a full head of steam, so as to make the passage as quick as possible, which shows beyond all doubt that little or no use could be made of

the helm during the passage, except to steady the craft on the course adopted just before they entered the passage between the piers where the disaster occurred.

Reliable means to ascertain with certainty what force it was which caused the craft to make leeway during the passage is not exhibited in the record, nor is it necessary to decide that point as it was plainly a rash act to undertake to steer the craft through that passage on a windy day, when the banks of the river were full, in the face of the dangers which the evidence satisfies the court would necessarily be encountered in such an attempt. Neither the state of the water nor of the wind was such as to furnish any just excuse for the master or pilot, as they might have chosen the other passage, or have taken proper and seasonable measures to leave back one of the barges for the next trip.

Ship-owners are responsible for such a disaster if it results from the ignorance, unskillfulness, or negligence of the master or those in charge of the vessel. Where the master, being ignorant of the coast, sailed past the port to which he was destined and ran into another port in the possession of the enemy and was captured, the court of King's Bench unanimously decided that the implied warranty to provide a master of competent skill was broken by sending out one who was unable to distinguish between the two ports.

Ignorance and unskillfulness being proved, the attempt to set up inevitable accident is vain, as such a defense can never be sustained, even in a collision case, unless it appears that neither party was in fault. Loss or damage occasioned by such a disaster, where it appears that those in charge of the deck were incompetent to perform the required duty either from inexperience or want of knowledge of the route, or from negligence or inattention, cannot be regarded as being the result of natural causes, nor as falling within the exception contained in the bill of lading or contract of shipment.

Different definitions are given of what is called inevitable accident, on account of the different circumstances attending the disaster, but there is no decided case which will support such a defense where it appears that the disaster was occasioned by incompetency, unskillfulness, or negligence of the master or pilot in charge of the deck.

Service was not made in this case upon the barge, and, of course, the decree must be founded upon the fault of the steamer and those who were responsible for the unskillfulness and bad judgment exercised in her navigation.

Decree reversed with costs, and the case remanded with directions to enter a decree for the libellants and for further proceedings in conformity TO THE OPINION OF THE COURT.

The case of the *Mollie Mohler* is also reported in Wallace, vol. 21.

Appeal in admiralty from a decree of the circuit court of the eastern district of Wisconsin.

The Home Insurance Company of New York was the insurer of a cargo of wheat shipped on a barge appurtenant to the steamer Mohler, on the 12th of May, 1866, at Mankato, on the Minnesota River, in the State of Minnesota—the river then being high—and destined to Saint Paul on the Mississippi. The bill of lading contained the usual exception of "the dangers of navigation." The barge was wrecked by collision with one of the piers of a bridge just above the city of Saint Paul, at about eight o'clock on the evening of the day on which the voyage began, and was totally lost.

The insurance company paid the loss and filed its libel in the district court to recover the amount under its right of subrogation.

The answer set up that the accident occurred through a sudden and unexpected gust of wind which overtook the boat as she was about passing through the piers, and that she was therefore not answerable for the consequences of the collision.

The case was heard on the testimony introduced by the respondents, the libellants having called no witness.

The weather in the morning of the day when the boat set off was calm, but during the afternoon became rough and windy, so much so that the boat laid up at Mendota, near the mouth of the Minnesota River, and about 4 miles above the piers, on account of the wind. After sundown—that is to say, a few minutes after seven o'clock—she proceeded on her voyage, the wind having "abated," as the master said, or, according to the testimony of the mate, having "calmed down some." At eight the barge struck the pier, killing a man on board and sinking the barge. The night was starlight, and piers had signal-lights upon them.

On the trial there was great discrepancy between the testimony of the master and that of the mate as to the condition of the wind after the boat left Mendota. The master swore that there was no wind to affect the boat until the Julia, an ascending boat, got near the Mohler, while the mate said that the wind rose after the Mohler left Mendota, and blew hard by spells all the way down. They also disagreed as to the point where the Julia was met, the master saying that it was not more than a quarter of a mile above the piers, while the mate fixed the distance at 1½ miles.

From Mendota down to within a short distance of these piers, high bluffs, it should be stated, line the sides of the river and prevent boats feeling or being affected by the wind, but that just before reaching the piers the bluffs recede from the river and open so as not to operate as a protection from the wind; and that on reaching this point wind will be felt, and sometimes very strongly, though before arriving at this point it would not be. On coming near to these parts there was no doubt that the wind had not gone down, and that it was from a dangerous quarter, the south, the river here running east and a south wind tending to drive a boat on a pier.

"When we came within about half a mile of the piers [said the pilot], gusts came at times hard enough to split the posts of fences, but they lulled. Then a heavy gale struck us four or five lengths above the piers. We could not have then changed our course or made a landing. Everything possible to prevent a collision was done; but the collision was inevitable."

An expert witness—of the respondents, of course—on cross-examination, testified that within a quarter of a mile, or even less, the steamer and her tow could have rounded to and landed even in a hard wind from the south; and that not to do so in such a case would be bad seamanship.

Other witnesses testified that these piers increase the danger of the navigation; that vessels were very liable to be driven against such obstructions; that extraordinary precaution was necessary in going through them, and then that "a man is liable to be beat at it."

Both the district and the circuit court held that the officers of the steamer were guilty of a wrongful act in attempting to pass between the piers of the bridge in the state of the weather at the time, and condemned the steamer. From this condemnation her owners appealed.

Mr. J. W. Cary, for the appellants, argued that it was plain from the fact that the vessel had put into Mendota for the exact purpose of *not* running while there was high wind, that all evidences of high wind must have disappeared before the vessels came out, that no wind did, in fact, disturb them until they got to where the bluffs recede; that there, from the physical configuration of the land, occasional gusts of wind might come unexpectedly through the gaps as through a funnel, though no high wind were stirring; that such was the case here; and that where such a gust did come through such a place it was a true peril of navigation.

Mr. N. J. Emmons, *Contra:*

Mr. Justice DAVIS delivered the opinion of the court. It is insisted that the loss occurred through a peril of navigation, which was one of the exceptions contained in the bill of lading, and that therefore the carrier was excused from a delivery of the wheat. The burden of proof lies on the carrier, and nothing short of clear proof, leaving no reasonable doubt for controversy, should be permitted to discharge him from duties which the law has annexed to his employment. This burden has been assumed by the carrier, and the case was heard on the testimony introduced by the respondents, the libelant having called no witnesses.

It may be true, as the answer implies, that the boat would have safely made the passage if the wind had not driven her against the pier, but this does not solve the difficulty. The inquiry is whether the passage should have been undertaken at all in the general bent of the weather on that day. If the carrier had sufficient warning to put him on his guard, and chose to neglect it and take the chances of a venture, when common prudence told him there was danger in it, he cannot escape on the ground that the particular peril which finally overcame him was a sudden gust of wind. The general doctrine that a carrier is not answerable for goods lost by tempest has no application to such a case.

It is undeniable that the weather was boisterous during the after part of the day on which the loss occurred, and that the boat laid up at Mendota on account of the wind. It had at best only "abated" or "calmed down," when she left Mendota and proceeded on her voyage. There is a singular discrepancy in the testimony of the master and the mate as to the condition of the wind after the departure from Mendota, and as to where it was that the wind began to blow hard, the master swearing that there was no great wind until the boat met the Julia, and that this was but a quarter of a mile above the piers, the mate giving a very different account as to both facts. Both these officers had equal opportunities of judging, and there is nothing in the record affecting the credibility of either. In such a case the defense fails, for the respondents have no right to ask the court to prefer the testimony of one witness over the other, when there is nothing in the record to show that one is more reliable than the other.

Apart from this, there is enough in the evidence to establish satisfactorily that the weather had not cleared, nor the direction of the wind changed, and that the boat should either not have left her moorings at Mendota, or have landed at some proper point before the piers were reached. It won't do to say that the wind had moderated, and that the officers of the boat thought they could get through without trouble. They had no right to think so, for on such a day squalls were likely to arise at any moment, and it was bad seamanship, being forewarned, to attempt to go through such a dangerous place in the river. It is difficult at all times to make the passage of these piers, and especially so in sudden gusts of wind blowing from the south, which was the case on that day. And this difficulty is enhanced in the night-time and when the current, by reason of high-water, is increased.

Any prudent officer would have stopped until the weather became calm. At any rate, it was the duty of the master of the boat in question to have done so, and failing in this duty, he is chargeable with the consequences of his negligence, which, in this case, was lamentable, for not only was the property in his charge destroyed, but a human life lost. The officers of steamers plying the Western waters must be held to the full measure of responsibility in navigating streams where bridges are built across them. These bridges, supported by piers, of necessity increase the dangers of navigation, and river-men, instead of recognizing them as lawful structures built in the interests of commerce, seem to regard them as obstructions to it, and apparently act on the belief that frequent accidents will cause their removal. There is no foundation for this belief. Instead of the present bridges being abandoned, more will be constructed.

The changed condition of the country, produced by the building of railroads, has caused the great inland waters to be spanned by bridges. These bridges are to a certain extent impediments in the way of navigation, but railways are highways of commerce as well as rivers, and would fail of accomplishing one of the main objects for which they were created—the rapid transit of persons and property—if rivers could not be bridged. It is the interest as well as the duty of all persons engaged in business on the water-routes of transportation to conform to this necessity of commerce. If they do this, and recognize railroad bridges as an accomplished fact in the history of the country, there would be less loss of life and property and fewer complaints of the difficulties of navigation at the places where these bridges are built. If they pursue a different and contrary course, it rests with the courts of the country, in every proper case, to remind them of their legal responsibility.

DECREE AFFIRMED.

These decisions in the cases of the Lady Pike and the Mollie Mohler show how very important it is that Congress should pass laws in regard to bridges that will afford ample protection to navigation. Here is a bridge over a navigable stream, begun, without any authority of the laws of Congress, before 1866, and left in an unfinished state until 1870, with piers unreasonably close together, partly submerged at high water, oblique to the current, altogether making it "rashness to pass" such "a place of danger" in pursuit of the regular business of navigation at times when the other parts of the river were easily navigable to the best advantage. There seems every reason to believe that the bridge company was liable to damages, but under the rulings of the Supreme Court such redress is doubtful, and the steamboatman is little able to carry on a suit against a bridge company, often backed up by a great railroad interest.

MEMORANDA UPON THE BRIDGES ON THE OHIO RIVER SUBSEQUENT TO THE WHEELING BRIDGE CASE.

The act of Congress making appropriations for rivers and harbors, approved July 11, 1870, provided in section 5 for the detail of three engineers, whose duty it shall be to examine all the bridges now erected or in process of erection across the Ohio River, and to report, &c.

The officers detailed were myself, General Godfrey Weitzel, and Col. W. E. Merrill. Our final report is given in the Annual Report of the Chief of Engineers for 1871, pp. 397–457.

The same assistant engineers, Mr. Cotton and Mr. Bentley, and the same methods were employed on the surveys of the Ohio River bridges that had been used upon the Mississippi.

The most prominent feature of interest here at that time was the Newport and Cincinnati bridge, then in process of erection, which was being built as a pivot-draw, only 70 feet above low-water, while the navigation interest claimed it should be by the law 100 feet above low-water. The readiness with which the report on the Ohio can be consulted requires here no more than a reference to the distinctive features of the bridge. The law providing for the bridge between Cincinnati, Ohio, and Newport, Ky., grew out of that providing for the bridge at Steubenville, so that the debates in Congress on the subject which preceded the passage of that law became of interest, in order to ascertain the intention of the framers of that law.

All that is pertinent to this subject is given in the report of the Board of Engineers (Annual Report Chief of Engineers, 1871, pp. 435–440). A minute description of the bridge as first designed is given in the same report, and it contains a recommendation that the constructors should be compelled to raise it to the height of 100 feet above low-water for the security of navigation. The report of this board contains a fairly full account of all the bridges then built across the Ohio River. It also submitted a draught for a law regulating the bridging the Ohio River, with the reasons therefor.

Congress, by an act approved March 3, 1871, required the building of the Newport and Cincinnati bridge, as recommended by the Board of Engineers, and provided that the bridge company might file a bill in equity, in the United States circuit court for the southern district of Ohio, for reimbursement for expenses in making the change, if in their first plan they had not acted unlawfully. This suit has been commenced, but, at the date of this report, not decided. The decision will be looked for with interest in connection with the matter of reserved right which the United States laws make to remedy any injury to navigation by future legislation, although the case of the Newport and Cincinnati bridge is so peculiar that it cannot have very general application as a precedent.

Congress, by an act approved December 17, 1872, established a general law for bridging the Ohio River, essentially as recommended by the Board of Engineers. Every proposition to bridge the Ohio River, under its provisions, must have the approval of the Secretary of War; and in the case of the bridge just below Cincinnati, the plan was submitted to a Board of Engineers, consisting of General Simpson, Colonel Merrill, and Major Suter, Corps of Engineers. They decided that, at the site selected, a span of 500 feet was necessary to secure the clear navigable space which the law required. (Annual Report Chief of Engineers, 1876, Part II, p. 299.) Under this decision, the city of Cincinnati built a clear span of 500 feet, standing on piers 100 feet above low-water, upon the horizontal truss system, and without using steel or incurring any extraordinary expense. This is a great success for engineering in the interest of navigation.

The Board of Engineers which reported upon the Ohio River bridges has been again convened, to consider the question of a bridge at Evansville, where some new and important engineering questions have been raised.

Taken as a whole, Ohio River bridges have provided, under circumstances of great difficulty, very thoroughly for the unobstructed navigation of that river.

The following is a list of the bridges on the Ohio River below Pittsburgh:

Steubenville, Ohio.—Railway bridge.
Wheeling, W. Va.—Highway suspension bridge over main channel.
Bellaire, Ohio.—Railway bridge.
Parkersburg, W. Va.—Railway bridge.
Newport and Cincinnati.—Railway and highway bridge.
Covington and Cincinnati.—Highway suspension bridge.
Cincinnati, Ohio.—Railway bridge.
Louisville, Ky.—Railway bridge.

MEMORANDUM UPON THE MISSOURI RIVER BRIDGES.

These have all been built since the time when this investigation was ordered, and generally under the same requirements as in the laws for bridging the Mississippi.

The less kindly nature of the Missouri in its changing banks and shoals and the advantage of a less depth to the bed-rock made the option for a high bridge 50 feet above high water and spans (one at least) not less than 300 feet in the clear much more favorably received by bridge companies on the Missouri than on the Mississippi above their junction.

The gentle adaptable nature of the Mississippi River yields every advantage to free navigation, and yet submits to the worst conceivable obstructions without destroying them, although even here a limit to obstruction has been reached. The engineering of the bridges on the Missouri is, therefore, generally much better than that of the Upper Mississippi. For, while on the Mississippi all the bridges are on the low draw-bridge plan except the highway bridge at Saint Paul, those on the Missouri, at Saint Charles, at Leavenworth, and Omaha, are high ones; 50 feet above high-water.

Hence the conclusion is plain that the high-bridge alternative is not in itself impracticable, for it has been several times adopted in preference to the low-draw plan, under circumstances similar to the cases in which low draw-bridges have been given the preference upon the Mississippi.

Not having had the Missouri River bridges in my field of duty, I can give only a fragmentary account of them, which is as follows:

Saint Charles, *Mo.*, railway bridge. Three channel-spans 300 feet in the clear, 50 feet above high-water; three 300-foot deck-spans on the right and one such on the left of the channel-spans; approaches on iron trestles; maximum grade, 1 to 100. This is an admirable structure, designed and built by Smith & Latrobe, Baltimore Bridge Company. It occupied three years in building, being finished in 1871, at a cost of $1,797,186.19. This bridge was designed by General C. Shaler Smith, without any limiting provisions in the United States laws.

Boonville, *Mo.*, railway draw-bridge, 10 feet above high-water, with draw-openings 160 feet in the clear. Built with unexampled dispatch, and finished in January, 1874. (See Van Nostrand, vol. 10, p. 91.) General W. Sooy Smith, engineer.

Kansas City, *Mo.*, railway draw-bridge, 10 feet above high-water, with draw-opening 160 feet in the clear. Finished in July, 1870, Mr. O. Chanute, engineer. Full account by Mr. Chanute, published by Van Nostrand, 4to, with illustrations. This bridge is reported upon by Major Suter, Corps of Engineers, in Annual Report of Chief of Engineers for 1869, pp. 304–306.

Leavenworth, *Kans.*, elevated railway bridge, built 50 feet above high-water, one span of 340 and two of 315 feet (probably from centers). Finished in 1872. General W. W. Wright, engineer. Foundation sunk to bed-rock.

Atchison, *Kans.*, railway draw-bridge; clear openings of 160 feet. Probably 10 feet above high water. Recently built.

Saint Joseph, *Mo.*, railway and highway draw-bridge, with clear openings of 160 feet each, one span of 80 feet and three of 300 feet. Foundation sunk to bed-rock by plenum pneumatic process. Finished in June, 1873. Mr. Eddy D. Mason, engineer.

Omaha, *Nebr.*, elevated railway bridge 50 feet above high-water. One channel-span, 300 feet in the clear, other spans 250 feet. Finished in

1872. General W. Sooy Smith engineer for the foundations, which are tubes, sunk by pneumatic process to bed-rock.

List of bridges on Missouri River, authorized but not built.

At Glasgow, Mo.
At Lexington, Mo.
At Brownville, Nebr.
At Nebraska, Nebr.
At Sioux City, Iowa.

ABSTRACT OF LAWS FOR BRIDGING THE OHIO, MISSISSIPPI, AND MISSOURI RIVERS.

Act of Congress approved August 31, 1852, declared the suspension bridge over the Ohio River at—

WHEELING, VA., to be a lawful structure and a post-road. The highest point of this bridge is 91½ feet above extreme low-water, and 48 feet above highest water; for a width of 155 feet it has a height of 91 feet above low-water. The distance between centers of towers is 1,010 feet, and between the faces of the abutments 980 feet.

Act approved July 14, 1862, authorized the building of a bridge at—

STEUBENVILLE, OHIO, or at any point over the Ohio River above the mouth of the Big Sandy River. The provisions for the Steubenville bridge were that it should leave an unobstructed headway in the channel of the river of not less than 90 feet above low-water mark, and an unobstructed width of not less than 300 feet between the piers next to said channel or water-way; and one of the spans next adjoining thereto shall not be less than 220 feet in length. If constructed with a draw, it should be under the limitations of the section containing general provisions. This section allowed the bridge to be built either as a high bridge or draw-bridge. If built as a high bridge, it should be not less than 90 feet above low water over the channel, nor in any case less than 40 feet above extreme high-water, channel-span not to be less than 300 feet in width, and one of the next adjoining not less than 220 feet. If built as a draw-bridge the same shall be constructed with a span over the main channel 300 feet in length and not less than 70 feet above low-water mark, and one of the next adjoining spans not less than 220 feet, and also that there shall be constructed a pivot-draw in every such bridge in a navigable part, with spans of not less than 100 feet on each side of the pivot.

Act approved July 2, 1864, entitled

> An act to amend an act entitled "An act to aid in the construction of a railroad and telegraph line from the Missouri River to the Pacific Ocean, and to secure to the government the use of the same for postal, military, and other purposes," approved July first, eighteen hundred and sixty-two,

gave authority to the Union Pacific Railroad Company to construct bridges over the Missouri River and all other rivers for the convenience of said road: *Provided*, That the bridges be constructed with suitable and proper draws for the passage of steamboats, and in such manner as not to impair the usefulness of said rivers for navigation to any greater extent than such structures of the most approved character necessarily do.

By section 13 of the *act approved July* 1, 1862, the Hannibal and Saint Joseph Railroad Company was authorized to extend its road from Saint Joseph, *via Atchison, Kans.*, to unite with the road through Kansas, upon the same terms and conditions as provided for the Union Pacific Railroad Company.

Act approved February 17, 1865, declared that the bridge across the Ohio River from—

Cincinnati, Ohio, to Covington, Ky., when completed, shall be a lawful structure and post-road (highway suspension, Roebling's).

Act approved February 17, 1865, amended the act approved July 14, 1862, so as to authorize the construction of a bridge over the Ohio River at the head of the falls at—

Louisville, Ky., provided that it shall be 56 feet above low-water mark and with three draws sufficient to pass the largest boats navigating the Ohio River; one over the Indiana chute, one over the middle chute, and one over the canal. *Provided*, that the spans shall not be less than 240 feet in width, except the draw-spans; the draw-spans over the Indiana and middle chutes shall be 150 feet each side of pivot, and the draw over the canal 90 feet. (The company built a better bridge. See Annual Report Chief of Engineers, 1871, p. 419.)

By act approved July 25, 1866, bridges were authorized to be built at—

Quincy, Ill.,
Burlington, Iowa,
Hannibal, Mo.,
Prairie du Chien, Wis.,
Keokuk, Iowa,
Winona, Minn.,
Dubuque, Iowa,
Saint Louis, Mo.,
over the Mississippi River.

Kansas City, Mo., over the Missouri River.

The general provisions of this act were, that if built as high bridges they should be 50 feet above extreme high-water mark, with spans not less than 250 feet in length, and one main or channel span not less than 300 feet in length; if built as draw-bridges they shall have two draw-openings of not less than 160 feet in the clear, and next adjoining spans of not less than 250 feet, and should be 10 feet above high and 30 feet above low water. It provided that the bridge at Saint Louis should not be a suspension or draw bridge, but of continuous or unbroken spans, with the bottom chord 50 feet above the city directrix at its greatest span; that it should have at least one span 500 feet in the clear or two spans of 350 feet in the clear; that no span over the water at low-water mark should be less than 200 feet in the clear.

Act approved February 27, 1867, declared the railway bridge over the Mississippi River at—

Clinton, Iowa, to be a lawful structure and post-route.

Act approved March 2, 1867, appropriated $200,000 for building the—

Rock Island bridge. It provided that the ownership should remain in the United States; that the Rock Island and Pacific Railroad Company should have the right of way over said bridge and island for purposes of transit, upon the condition that the said company shall, before any money is expended, agree to pay half the cost of said bridge and half the expense of keeping it in repair.

Act approved February 21, 1868, authorizing the Southern Minnesota Railroad Company to build a bridge at—

La Crosse, Wis., subject to the terms, conditions, &c., of the act approved July 25, 1866, authorizing bridge at Quincy, Ill., &c.

Act approved July 20, 1868, authorized the building of a bridge over the Missouri at—

Fort Leavenworth, Kans., and one at Saint Joseph, Mo. The bridges must be 50 feet above extreme high-water mark to the bottom chord, and have spans of not less than 250 feet in the clear.

Act approved July 20, 1868, provides that the bridge at—

SAINT LOUIS, MO., shall have one span of at least 500 feet clear between the piers.

Act approved March 3, 1869, appropriated $500,000 for the construction of the—

ROCK ISLAND BRIDGE.

Resolution approved March 3, 1869, gave consent to the erection of a bridge over the Ohio from—

CINCINNATI, OHIO, to NEWPORT, KY.; provided that the bridge be built with an unbroken or continuous span of not less than 400 feet in the clear from pier to pier; in all other respects in accordance with conditions, &c., of an act to establish certain post-roads, approved July 14, 1862.

Joint resolution approved April 7, 1869, authorizes the building of a bridge at—

PADUCAH, KY., with a continuous span of not less than 400 feet in the clear; in other respects, in accordance with act approved July 14, 1862.

Act approved July 11, 1870, directed the Secretary of War to detail three engineers to examine all bridges now erected or in process of construction across the Ohio River, and to report whether such bridges will interfere with the free and safe navigation of the river, and, if they do, to report what extent of span and elevation above water will be required to prevent such obstruction, and an estimate of cost to change them.

Act approved July 14, 1870, amending act approved July 20, 1868, allowing the bridge at—

SAINT JOSEPH, MO., to be built on the terms and subject to limitations of the act of Congress approved July 25, 1866, provided if built as a draw-bridge the spans of the draw shall not be less than 200 feet in the clear on each side of the central point.

Act approved March 3, 1871, made it unlawful to proceed in the construction of the bridge over the Ohio River from—

CINCINNATI, OHIO, to NEWPORT, KY., now being constructed, unless so constructed that the channel-span of 400 feet, as located, shall have a clear headway at low-water of 100 feet below any point of the span. In such case no draw would be required. Further required that proposed changes by the company should be submitted to the Secretary of War for his approval. It also provided that the company could, after making the changes, file a bill in equity in the United States circuit court, and gave the courts jurisdiction.

Act approved February 24, 1871, authorized the construction of a railway and highway bridge over the Missouri River at—

OMAHA, NEBR., under the provisions of the act approved July 25, 1866, authorizing the bridge at Quincy, &c., provided that if constructed as a draw-bridge it shall have draw-spans of not less than 200 feet in the clear on each side of the pivot-pier.

Act approved March 3, 1871, authorized the bridging of the Mississippi River at—

LOUISIANA, MO., and provided that if built with unbroken and continuous spans it should not be of a less elevation than 50 feet above high-water mark to the lower chord of the bridge, nor should the spans over the main channel be less than 350 feet in length, and provided that if built as a draw-bridge the draw should be over the main channel with spans not less than 200 feet in length in the clear.

Section 6 authorized the construction of a bridge over the Missouri River within 9 miles of—

GLASGOW, MO., provided that the said bridge shall be made with unbroken and continuous spans of the same height and lengths as provided for a high bridge at Louisiana, Mo.

Act approved March 3, 1871, appropriated $500,000 for completing the—

ROCK ISLAND BRIDGE; it being an unexpended balance covered into the Treasury.

Act approved March 5, 1872, authorized the building of a railway and highway bridge by the "Saint Joseph Bridge Building Company" at—

SAINT JOSEPH, MO., either as a high bridge or low draw-bridge; if high not less than 50 feet above extreme high-water mark.

> Nor shall the spans of said bridges be less than 350 feet in length, * * * and the main span shall be over the main channel of the river, and not less than 300 feet in length.

If built as a draw-bridge, the provisions are the same as in the act approved July 25, 1866, authorizing the bridge at Quincy, &c. This act provides that a plan of the bridge must be submitted to the Secretary of War for his approval. The company shall not assign the charter which it now holds by assignment from the Saint Joseph and Denver City Railroad Company, nor construct any other bridge.

Act approved April 1, 1872, authorized the building of a bridge over the Mississippi River within 15 miles of—

CLINTON, IOWA, not to interfere in any manner with approaches or piers of the bridge now constructed at Clinton, under the limitations as to dimensions of spans as provided in the act approved July 25, 1866. All railroad companies desiring to use it shall be entitled to equal rights in the passage of it, upon terms and conditions prescribed by the Secretary of War.

Section 5 provides that the Secretary of War shall have power to make regulations for the security of navigation, and the bridge shall be changed at the expense of the owner.

Section 6 authorizes a bridge at—

MUSCATINE, IOWA.

Section 7 authorizes a bridge at any point between the counties of—

WHITESIDES AND CARROLL, ILLINOIS, and JACKSON AND CLINTON, IOWA.

Section 8 authorizes a bridge to be built at—

LA CROSSE, WIS., by the Milwaukee and Saint Paul Railroad Company.

Act approved May 1, 1872, amends act approved March 5, 1872, but did not change any of the required lengths and heights of span.

Act approved May 11, 1872, authorized a bridge at—

BOONVILLE, MO., to be built under the requirements of act approved July 25, 1866.

Act approved May 15, 1872, authorized a bridge over Lake Saint Croix at—

HUDSON, WIS.; draw to be 320 feet long over all, with two spans of 140 feet in the clear, for the passage of boats; one span, 136 feet in the clear, for the passage of rafts. No provision was made as to height.

Act approved May 17, 1872, authorizes a railway and highway bridge to be built at—

QUINCY, ILL., under the same provisions as in act approved April 1, 1872, for a bridge at or near Clinton.

Section 7 authorizes a bridge at—

WARSAW, ILL. A provision of the act was that this bridge be commenced within eighteen months.

Act approved May 25, 1872, authorized a bridge at—

FORT MADISON, IOWA, under the provisions contained in act approved April 1, 1872, for a bridge at Clinton, &c.

Act approved June 4, 1872.—All bridges hereafter constructed over the Mississippi River, under authority of any act of Congress, shall be subject to all the terms, restrictions, and requirements as to length and height of spans, &c., of the act authorizing the bridge at or near Clinton, Iowa, approved April 1, 1872.

Act approved June 4, 1872, authorizes the Davenport and Saint Paul Railroad Company to pass their cars over the bridge at Rock Island, under certain provisions.

Act approved June 4, 1872, authorizes the building of a railway and highway bridge at—

NEBRASKA CITY, NEBR., under the provisions of act approved July 25, 1866. Section 2 provides that the charter shall be for the use and benefit of any person or corporation who shall complete the bridge, and that the said corporators may be compelled to make the transfer of the charter by any court having jurisdiction.

> *Provided*, That the said Nebraska Bridge Company and their associates shall fail to commence in good faith the erection of said bridge within one year from the passage of this act and complete the said bridge without unnecessary and unreasonable delay in accordance with the provisions of this charter.

Act approved June 4, 1872, authorizes building a railway bridge across the Missouri River at—

BROWNVILLE, NEBR. If high, 50 feet above high-water; spans, 250 feet; main span, 300 feet; if a draw-bridge, draw-openings not less than 200 feet; adjoining spans, 250 feet; 10 feet above high-water.

Act approved June 10, 1872, authorizes a railway bridge to be built at or near the city of—

RED WING, MINN., under the provisions of act of July 25, 1866.

Act approved December 17, 1872, authorizes the bridging of the Ohio River, for railroad or other purposes, by any one having authority therefor, upon compliance with the provisions and requirements of this act. Every bridge above the mouth of the Big Sandy shall have at least one span of a height of not less than 90 feet above low-water and of not less than 40 feet above local high-water; that this high span shall give a clear opening of at least 400 feet between the piers, and shall be placed over the main channel. If the high span is not over the low-water channel, suitable arrangements to be made elsewhere to permit the passage of single boats at low-water. All bridges over the Ohio below the Covington and Cincinnati suspension bridge shall have in addition to the high span prescribed above a pivot-draw with two clear openings of 160 feet each. If the conditions of this act cannot be complied with the Secretary of War shall appoint a board of three experienced officers of the Corps of Engineers to examine the case, and may on that recommendation authorize such modifications in the requirements of this act as will permit the construction of the bridge. All bridges over the Ohio shall maintain such lights as may be required by the Light-House Board.

This act authorized the building of one bridge at—

WHEELING, W. VA., with a span over the main channel of not less than 350 feet in length.

Joint resolution number ten, approved April 7, 1869, authorizing a bridge at—

PADUCAH, KY., was repealed by this act.

Standard steam-pressure for tow and freight boats on the Mississippi River and tributaries changed from 110 to 150 pounds by this act.

Act approved March 3, 1873, authorizes the Saint Clair and Carondelet Bridge Company to bridge the Mississippi from the southern part of—

Saint Louis.—The bridge must have two spans over the main channel of not less than 500 feet in the clear at low-water mark, no span over the water at low-water mark to be less than 250 feet in the clear. The elevation of the bridge over the main channel shall not be less than 100 feet above low-water mark, measuring to the lowest part of the superstructure, or in case of arch spans, to the lowest point of the center of the arch; that it shall have two railway-tracks, two highway-tracks, and two foot-walks of not less than 8 feet in width.

Act approved March 3, 1873, authorizes a railway-bridge over the Missouri River at—

Lexington, Mo., to be built under the same provisions as contained in act approved July 25, 1866.

Act approved June 6, 1874, legalized the railway and ponton bridge across the Mississippi River at—

Prairie du Chien, Wis.—Section 4 of this act provides that the bridge authorized at or near—

Clinton, Iowa, by act approved April 1, 1872, may be constructed as a pile and ponton bridge, with a draw not less than 408 feet in width.

Act approved June 22, 1874, authorized the Milwaukee and Saint Paul Railway Company to construct a bridge at a point heretofore selected at—

La Crosse, Wis.; a board of engineers to be convened to report what accessory works are necessary to secure a straight channel-way for navigation; the board to determine the location of piers and height of bridge; company not to proceed with the building until report of the board is approved by the Secretary of War; superstructure not to be commenced until accessory works are constructed; a provision that the said company shall not charge more than $3 a car for each freight-car transported across said bridge.

Act approved June 23, 1874, appropriated $23,400 for—

Rock Island Bridge, for alterations and repairs and additional machinery (for draw of bridge), and for care and preservation, one-half of which sum to be reimbursed by the Chicago, Rock Island and Pacific Railroad Company.

Act approved March 3, 1875, act amendatory of the act approved March 3, 1873, authorizing bridge over the Mississippi at—

Saint Louis, Mo., allows two straight continuous spans of not less than 450 feet in the clear. Section 2 requires the company to close Cahokia Bend if the site on plan numbered "2" submitted to the Secretary of War be accepted.

Act approved March 3, 1873, authorized a ponton wagon-bridge across the Mississippi River at—

Dubuque, Iowa, subject to all the terms, &c., of act legalizing a ponton railway-bridge at Prairie du Chien, Wis., approved June 6, 1874, subject to the provision that it shall have a draw 500 feet wide, and that plan and location shall be subject to the approval of the Secretary of War.

Act approved July 6, 1876, authorizes the city of—

La Crosse, Wis., to construct a pile and ponton bridge across the Mississippi River, subject to all the terms of act legalizing the Prairie du Chien railway ponton bridge approved June 6, 1874, with the modifications that it shall have one draw of not less than 400 feet, and that plans and location must first be submitted to the Secretary of War for his approval.

Act approved July 8, 1876, authorizes the Nebraska City Bridge Company to build a ponton railway-transit and wagon bridge across the Missouri River at—

NEBRASKA CITY, NEBR., with a draw 300 feet wide; design and drawings of the bridge and a map of the location for one mile above and one mile below the bridge shall be submitted to the Secretary of War for his approval before the bridge shall be built.

Act approved August 15, 1876, authorizes the Sioux City Bridge Company to build a railway and highway bridge over the Missouri River at—

SIOUX CITY, IOWA.—It may be built as a high bridge 50 feet above extreme high water, all spans 300 feet; or as a draw-bridge, same dimensions, &c., as act approved July 26, 1866. If the company elect, the Secretary of War may authorize the building of a pile or ponton bridge subject to the restrictions in the act legalizing the Prairie du Chien bridge, approved June 6, 1874, except that it shall have one draw 400 feet wide in the clear; plans of bridge and location to be subject to the approval of the Secretary of War.

CHAPTER VI.

GENERAL ACCOUNT OF THE WAY THE SURVEYS AND INVESTIGATIONS HAVE BEEN MADE.

Description of surveys made in 1866, '67, '68, '69, and '76—Circumstances under which the maps and reports were prepared—LIST AND DESCRIPTION OF ORIGINAL MAPS—COMPILED MAPS ON A SCALE OF TWO INCHES TO A MILE—Map on scale of an inch to six miles—LIST OF MAPS COLLECTED AND USED IN THE COMPILATION.

Surveys in 1866.—This description of surveys includes not only those made at bridge sites, but such as were made for the purpose of improving places of difficult navigation, more particularly of the river between the Falls of Saint Anthony and Rock Island. The subject of improvement will be treated in a separate report, but the surveys are all described here, as they were really included in the requirement of the bridge investigation "to survey the whole river." The same parties did the field-work for both purposes. Mr. J. P. Cotton, civil engineer, was from the first employed on this work, and for much the larger portion of the time he was in charge of these surveys. He has, also, with other assistants, under my direction, prepared all the maps and other drawings, and aided me in every part of this work.

The short time remaining between my arrival in Saint Paul, in August, 1866, and the close of the season, coupled with the fact that my report upon these surveys had to be submitted to Congress at its next session, in December, precluded the possibility of making a continuous survey of more than a small portion of the river upon which I was to report. I therefore concluded to make a reconnaissance of the whole river from Saint Anthony to Saint Louis, and to make detailed surveys at points where navigation was obstructed, and at bridges, and at proposed and probable sites of bridges.

For this reconnaissance the steamer G. B. Knapp was chartered at $1,000 per month. She was a new steamer, built to run between Stillwater, Minn., on Lake Saint Croix, and Saint Paul, Minn. Her draught, when light, was only about 20 inches. The light draught enabled her to run in any channel that could be navigated by freighting steamboats. The boat was in charge of a captain, a pilot, two engineers, firemen, and deck-hands. Difficulty, as usual, was found in organizing a party to make the instrumental surveys. This was the first work in that section of the country requiring engineers possessed of practical knowledge in river surveying, and want of time prevented bringing them from other places.

Mr. C. C. Smith, an engineer of ability, whom I employed, succeeded in getting together the following party, viz: T. P. Gere, J. P. Cotton, A. D. McSweeny, C. H. Conwell, and H. D. Van Pelt. These men had come to this part of the country for various reasons, and had been engaged upon railroad surveys. One of them, Mr. Cromwell, with mental acquirements and aims well fitted for our work, had come for his health, which he could not secure, and his loss was much felt in my subsequent work. Taken as a whole, the party at the outset was a make-shift, such as every engineer has to use when his chance for success is only to do the best he can. They all did the best that could be expected in this line of work, and some of them succeeded so well as to be highly appreciated afterward upon other river work where they are now employed. The whole party consisted of forty-one persons, as follows: 1 engineer in charge, 5 assistants, 4 chainmen, 4 flagmen, 1 steersman, 10 axmen, 2 rodmen, 10 boatmen, 2 cooks, 1 watchman, 1 steward. Other men were employed from time to time in the place of those who were sick or disabled by accident; so that the effective party usually numbered 36 to 40 men. It was essential to have men who could handle and row a boat, so that in hiring men we were confined to this class. Trouble, of course, was had with them, the most of whom were steamboat hands never long content at one thing or in one place. The party would barely get into working order when it would be crippled by one or more of the boatmen leaving. New ones employed in their places had to be instructed. It is the old story, and only mentioned here to show that we were no better placed than others had been. To lodge this party, a flatboat, which had been built to carry produce down the river, was purchased and fitted up. This boat answered very well for the purpose. although it was too small for comfort. It was purchased for $650, and fitted up for $200 additional. There were employed upon this boat two men to take care of it, two cooks, one steward, and one watchman.

A transit-line was to be run on each bank as near the water's edge as practicable, the topography along the line being noted by the transit-man; stakes to be set at hundred-feet intervals to enable the sounding party to fix the ends of their sounding-lines. "*Towheads*" (a name given to an embryo island, or the last vestiges of one that is washing away) were located by triangulation. Mr. Gere was given charge of one of these parties, and Mr. McSweeny the other, at the first start. Mr. Gere performed his new duties with success, and he remained during the first season.

Each transit party was made up of one transitman, two chainmen, three axmen, two flagmen, and an instrument carrier.

The level-line was confined to one bank. It was to be continuous, touching the water surface at intervals of not more than 1,000 feet, and, if practicable, as often as each 500 feet. All high-water marks were to be connected with it, and special pains was enjoined to search for them. It was found that the knowledge of those living on the river, concerning the level of high or low water was unreliable, and it was only in rare cases that definite marks could be found. When good marks were found there was frequently an uncertainty as to the knowledge of the date. Bench-marks were to be established at intervals of not more than one mile. Trees had to be used generally as a matter of necessity, and if in the future they cannot be found, attention must be paid to this narration of the circumstances. Whenever the survey included towns the bench-marks were to be made upon the most presumably permanent objects that could be found in them within practicable distances of the surveyed lines. Fortunately this delicate and important work was at the outset assigned to Mr. Cotton. The level party consisted of a leveler and two rodmen.

The topographer was intrusted with getting the character of the bottom-lands, terraces, and bluffs adjacent to the lines run along the river. When the survey reached a part of the river where it was divided into two or more channels by islands, he was placed in charge of a party to meander the islands with compass. He also assisted in locating submerged bars, and in all the various measurements of special localities, in velocity and discharge observations, &c. This position was given to Mr. C. H. Conwell. The topographer was assisted by two chainmen and as many axmen as special occasion required.

Sounding-lines were run across the river as often as every 500 feet, usually in a direction diagonal to the shore. Each line was started from a point on a transit-line, this point being noted in the sounding-book by the recorder, and the distance from the line to the first sounding estimated. The boat was then rowed at a uniform rate, and soundings were taken at regular intervals, as near as could be estimated; on reaching the opposite bank, the recorder noted the station of the transit-line, and estimated the distance from the last sounding to it. When soundings were made between the shore and islands, the lines were run to the points on the island that had been fixed by triangulation. The sounding-party consisted of a recorder, sounder, and four oarsmen.

In this method of sounding a river a great many soundings can be made, but it very imperfectly fixes their position on a map, even when the greatest effort is made to secure uniformity in the time of sounding and rowing. But this attempt at cadence requires the soundings to be made at intervals which often miss the most important features of the bottom, and the pole of convenient length sometimes does not reach the bottom in deep places. Sometimes the grounding of the boat on shoals and when approaching the shore destroys all uniformity in the work and the regular spacing of the soundings on the lines marked is wrong. One-tenth of the number of soundings made with judgment, where the actual position is fixed, is of far greater value. We have found that with an instrument having a micrometer attachment to give the distance by measurement of the image of a rod of known length, and a compass bearing to the place, will fix the point well enough for ordinary purposes. This method serves well to map the crests of sand-bars; and then a few soundings in the deep intervening parts are all that is required to show the actual state of the river.

Reductions of the depths to any one plane, in shoal rivers with sandy bed, cannot be done with any propriety, for the bed changes with the rise and fall of the water, and has no permanent form. At best it is condition that we ascertain, and for engineering purposes the depths have no value beyond a knowledge of the ruling navigable depth. Given the volume of water and the slope and the kind of bed, we can deduce the navigable capacity a stream can be made to have. This is a fact that is not generally known or apprehended.

Gauges to measure the rise and fall of the river during the survey were established at Minneapolis, Minn., above the falls, Saint Paul, Minn., Winona, Minn., Prairie du Chien, Wis., and Clinton, Iowa.

Mr. Smith was directed to commence work at Fort Snelling (at the mouth of the Minnesota River), to instruct the assistants and men in the duties required of them, during the time I was organizing and instructing the parties for the examination and report upon the Minnesota River, the Cannon and Zumbro Rivers, and upon the Fox and Wisconsin Rivers. He made a commencement on the 13th of September. The survey was continued under the direction of Mr. Smith, until the 21st of September, when he received, and with my permission accepted, the offer of more permanent employment on the Minnesota Valley Railroad. The party was then placed in charge of Mr. H. C. Long, civil engineer. Before I joined the party a continuous survey had been made of the river from Fort Snelling to Red Rock, a distance of 13 miles; but no reliable current measurements had been made.

On the 23d of September, all of the parties for the other river surveys in my charge having been started, I closed my office in Saint Paul and went on board the steamer Knapp to give personal attention to the surveys and examinations of the Mississippi. The quarter-boat was taken in tow by the steamer Knapp. Capt. N. F. Webb of steamer Itaska, of Northwestern Union Packet Company, was engaged to point out those places at which the greatest obstacles to navigation were usually found. His long experience as captain of steamers on this river made him familiar with the needs of navigation as well as the difficulties attending it. His good sense and kind, manly character endeared him to us all. He subsequently lost his life, by an accident, in the public service.

Proceeding on board the *Knapp* to Red Rock, the quarter-boat was taken in tow and the reconnaissance sketches begun. One of these was made by me to acquaint myself with the character of the river. Distances were estimated, and the local directions were taken from the positions of the sun, checked occasionally by a compass. My attention was specially given to noting characteristics of the river. The widths were checked occasionally by triangulation. This course of observation was a valuable means of instruction, and the record was useful for future reference. I would advise every one put in charge of a river so little known as this was to pursue such a course, for it gives one ideas fresh from nature, and enables him to appreciate the views of others.

The other sketch made by us on the steamer Knapp was made by Mr. H. Custer. In this, much more care for accurate representation of course and distance was attempted. The distances were estimated by him at the rate of the boat's motion, and his courses were taken by a compass all the time. At the same time soundings were being made and recorded. The result when worked out was a disappointment to us. The rate of a steamboat on the Upper Mississippi in low-water is exceedingly variable. On approaching a shoal the valves of the engine will be shut off so that the vessel barely moves, being kept, as it were, balanced in the control of the pilot, to go either back or forward as may be best. During this time the steam accumulates in the boiler, and when the shoal is passed full power is let on urging the boat on rapidly until the next shoal requires the repetition of the same exercise of judgment. Thus it is, measured by time, a steamboat may be longer passing one or two hundred feet of shoal than in passing 1 or 2 miles of deep pools. Mr. Custer had not had enough experience at this kind of river work to make due allowances for the ever varying rates. The steamboatman himself, by long experience and observation, judges very well about this matter of average speed, but I have found not only on the Mississippi, but on the Missouri in 1856, that even the pilots much overrate velocity.

We found the carefully prepared sketch of Mr. Custer nearly worthless, and have never used it to any extent. Another disclosure was that the man sounding while the boat was in motion, always found a great deal more depth of water than there really was. I mention this as a caution against receiving reports of such soundings where any important conclusion depends upon them. We stopped a while at Robinson Island and bar, where a base line was measured and the features of the island and bar determined. The next point at which surveys were made was at Hastings, Minn., where a railroad bridge had been proposed. Here the volume of the river was measured with mid-depth floats. Between Hastings and Prescott, particularly in the vicinity of Prescott Island, there were very bad sand bars that greatly obstructed the navigation of the river, and the survey was made continuous between the two places, a distance of 2½ miles. The position of the sand bars was fixed by triangulation. This was the system used in locating bars throughout the survey of this season. An examination was made of Lake Saint Croix up to Stillwater, and a map made of the narrow places at Catfish Bar, and opposite the mouth of Willow River. The volume of discharge from the lake was also measured.

At the mouth of the Cannon River, the party made a short survey, and measured the volume of water flowing from this small river, because it was one of the rivers upon which I was to report. A survey was made ot the west or Wacouta channel, one of the three mouths by which the Mississippi enters Lake Pepin. This is the most favorable one for navigation, although sometimes too shoal. The entrance to the others from the lake is more difficult. The middle channel was sketched and sounded out by the steamer Knapp, but the northern one was not visited this year for want of time.

The party then proceeded to the foot of Lake Pepin, where a continuous survey of about 13 miles of river was made. This part of the river includes the mouth of the Chippewa River and some of the most troublesome bars on the Mississippi below Lake Saint Croix. Both banks were surveyed, the larger islands meandered, and nearly all the sloughs and all of the navigable channels sounded out. All bars having a defined outline were located by triangulation. A continuous line of levels was run the whole distance, particular pains being taken to observe the difference in level of the water-surface above and below the crests of bars. Bench-marks were established and all high-water marks found, connected with the line of levels. The channels below Alma, Wis., were also run out and sketched in the same manner, and at Alma the volume was measured with mid-depth floats.

While the party was making this survey, I took passage on a very small steamboat, drawing about 12 inches, and ran up the Chippewa River to the head of the Chippewa River delta, making sketches on the way. The little steamboat had much difficulty in navigating. She was poled around sharp turns, and the passengers sometimes went ashore and walked. We returned in a skiff by the other mouth, known as "Beef Slough." This slough is deeper than the former channel for half the way down, when it is lost in numerous diverging channels choked with trees, and barely passable for a canoe. It furnishes a most interesting subject for study. Lake Pepin is a consequence of the deposit of sand from the Chippewa River.

On the 1st of October surveys were made in the vicinity of Minneiska, including the mouth of the Whitewater River, and at Chimney Rock Bar. On the day after, at Rolling Stone Bar, three miles above Fountain City, Wis.

The party then proceeded to Winona, at which place a railroad bridge had been authorized by Congress. The survey began on the 3d, and was completed on the 4th of October. It extended over about 4 miles of the Mississippi between the mouth of Straight or Rolling Stone Slough and a point about 1 mile below the city. The direction and velocity of the current were determined in two places.

We then went to La Crosse, Wis. Here the building of a railroad bridge had been considered by the Southern Minnesota Railroad. We commenced to survey about 2 miles above, and extended to some distance below the town, in order to include all probable bridge-sites; in all, about 4½ miles. The volume of the whole river was measured at La Plume Island. Velocities of current were measured in several other places, giving us the volume of the main river at La Crosse.

On the 7th of October, we made a small survey in Coon Slough and at the town of Bad Axe, Wis.

At Prairie du Chien, another railroad bridge had been authorized, and a survey was made, commencing at the head of the island 2 miles above the town, and extending down so as to include the mouth of the Wisconsin River. The survey was made to cover the probable location of the bridge. The bars at the mouth of the Wisconsin River were located by triangulation, and the survey lines were run up that river for a short distance. Current-measurements were made at several places. This survey was completed on the 10th of October.

On the 11th of October, surveys were made of a small extent of river at Guttenberg, Iowa, and at Cassville, Wis., where navigation had been obstructed by sand-bars during low water in previous years, and some abortive attempts at improvement had been made.

The next point surveyed was at Dubuque, Iowa, where Congress had authorized another railroad bridge. The survey was commenced on October 12, at the State line between Wisconsin and Illinois, about one-half of a mile above Dunleith, Ill., and extended to the mouth of Catfish Creek, 2 miles below Dubuque, Iowa, the whole length of river surveyed being about 4½ miles, and it was finished on October 14. The volume of discharge and the direction and velocity of the current were measured here.

The next survey made was at the railroad bridge at Clinton, Iowa, on October 15, 16, and 17. The survey commenced at Fulton, Ill., and extended to Beaver Island, below Clinton, a distance of 3 miles, and was finished October 17. It included a complete survey of the bridge, both of its substructure and superstructure. A fuller set of current-observations were made here than at any previous place. The method was an improvement upon our previous practice and was the result of experience. It was followed in all our subsequent current-observations at bridge-sites. The English engineers on the International Bridge over the Niagara at Buffalo in 1870 adopted it from us, and Mr. Gurowski gives an account of it in his interesting report on that bridge. As a simple and reliable method it seems to leave nothing to be desired, giving both direction and velocity, and a description of it is inserted here.

Floats of joists 4 to 8 feet long and 2 inches by 3 inches, in section, were used, sunk to near the surface of the water, bearing little flags, to make them readily seen. They were started some distance above the bridge, and allowed to pass through it, their positions being determined every thirty seconds by angles measured from each end of a measured base on shore. A time-keeper, with watch in hand, stood midway between the two observers, and five seconds before the even half-minute he called "Ready!" The observers at the theodolites directed the telescopes to the flag of the float and kept it in view as it floated until the timekeeper called "Time!" at the even half-minute. The angles were then read and recorded in the note-books. Similar observations were made above and below the bridge. Where the distance between the theodolites was long, or where there was noise so that the voice could not be heard, flag-signals were used to denote "ready" and "time."

It is well to state here, in view of the expensive and troublesome way in which these floats are sometimes made, that it can be done very simply. A bag with a slit left in it large enough to insert the hand is tied at the bottom end of the stick used as a float, into which sand, gravel, or stone can be inserted until the proper submergence is obtained. A sliver from a shingle makes a good flag-staff, which can be stuck in the upper end in a small hole bored for the purpose. Little strips of light cloth of different colors should be at hand to be used as flags, and small carpet-tacks will readily fasten them to the little flag-staff. These are so cheap that after using they may be thrown away if it is expensive to pack them up and transport them to another place.

On October 17, the steamer Knapp towed the quarter-boat, with party, to Le Claire, Iowa. The river was at this time so low that the crossing of the rapids was only attempted by very small steamers, and with these it was difficult to do, and attended with considerable risk. In view of this, and of the uncertainty of being able to get back with the Knapp if the river should continue to fall, I decided to turn over the quarter-boat to General J. H. Wilson, Corps of Engineers, discharge a portion of the party, send the steamer Knapp back to Saint Paul, and make such surveys as were required below this point with a smaller party, transporting it from place to place by the regular packet-steamers or in our own skiffs. All surveys made up to this date had been rapidly plotted in the evenings and while the quarter-boat was being towed from place to place. These plats and the note-books were intrusted to Assistant McSweeney, with direction to return to Saint Paul on board the steamer Knapp.

From Le Claire to Saint Louis (except over the Rock Island Rapids and Des Moines Rapids) the sketching was continued by Mr. Custer from the pilot-house of the steamers running regularly on this part of the river. He thus managed, by several changes, to sketch the whole river by daylight, but the result did not equal my expectations. The party, as reduced, numbered about 20 men, all told. These, with the necessary instruments, rods, chains, &c., and with four skiffs, made the surveys below Le Claire.

We arrived with this party at Burlington, Iowa, October 21, where a railroad-bridge had been authorized by Congress. Our survey commenced about 1 mile above the town and extended to a point about 1½ miles below it, a total distance of about 4 miles, covering every available site for a bridge that would give the Missouri River Railroad connection to the east. Here good discharge and current observations were made. This survey was finished October 24.

From Burlington the party rowed down to Keokuk, Iowa, a distance of 49 miles, in the skiffs, arriving there on the 26th. Having a few hours before the steamboat left for Quincy, we made a survey of the river in the vicinity of Keokuk, running about 2 miles along the river, where railroad-bridge had been authorized by Congress. Time being important, we trusted to the notes of General Wilson's survey of the rapids, designed by him to furnish data for a plan of improvement. We left this place on the evening of the 26th, for Quincy, Ill., on one of the regular steamboats plying between Keokuk and Saint Louis.

At Quincy surveys and preparations had been made to commence the building of the railroad-bridge authorized by Congress, but the exact location had not been fixed upon, or at least not made public. Borings had been made on different lines above the town and opposite the lower part of it. The survey was therefore commenced well up the river, and run down below the lowest site deemed practicable for a bridge, that would be accessible, a total distance of 3½ miles. The islands and sloughs were meandered, and numerous soundings were made in the main channel and island chutes. Observations for the direction of the current were made at the proposed sites above the town, and the bars in that part of the river were located. No levels were run at this place, the leveler being employed in meandering islands, locating bars, &c. The water-surface was referred to the city levels, the datum-plane of which was said to be the lowest water. The water-surface at the time, referred to this, was 2.14 feet.

The party then went in the skiffs to Hannibal, Mo., where Congress had authorized another railroad bridge. The survey at this latter place was commenced about one mile above the town and extended about one mile below it, a total distance of three miles. It occupied us on November 1 and 2. The survey here included the usual transit lines on each bank of the river, the meandering of the islands, the taking of levels and soundings for the whole distance. There was also made a full set of observations for the direction of the current in front of the town, and observations for the discharge of the river. A shoal injurious to navigation, near the landing at the upper end of the town, was located by triangulation.

Hannibal was the last point on the river between Saint Paul, Minn., and Saint Louis, Mo., at which Congress had authorized, or any one had proposed, to build a bridge.

Having finished the survey here, the whole party was discharged except the assistants, who were directed to proceed to Saint Paul, Minn., to prepare the maps.

In addition to the work of this main party under my supervision, Mr. Frank Cook, civil engineer, had, in October, made a survey of the Mississippi River from the bridge above Saint Anthony Falls to Meeker's Island, 2.62 miles below the falls. This survey included the falls, and the dams, flumes, mills, &c., near them, with a line of levels from the bridge to Meeker's Island. Mr. Cook also made a reconnaissance of the river from Meeker's Island to Fort Snelling.

The preliminary report on all these surveys was submitted by me January 21, 1867, and is published as House Ex. Doc. No. 58, Thirty-ninth Congress, second session.

The following table shows the extent and location of the surveys made between September 13 and November 3, 1866:

Locality.	Date.	Left bank, miles run.	Right bank, miles run.	Islands, bars, &c., miles run.	Levels, miles run.	Sounding-lines, total length.	Number of sounding-lines across river and chutes.
	1866.						
Falls of Saint Anthony to Meeker's Island	....	2.75	2.75	....	3.00	....	....
Fort Snelling to Red Rock	Sept. 13 to Sept. 24	13.5	13.75	4.00	16.00	31.25	200
Hastings, Minn., to Prescott, Wis	Sept. 24 and 25	4.5	2.00	2.50	6.00	9.00	65
Head of Lake Pepin	Sept. 26	1.50	2.25	3.00	0.50	6.75	44
Mouth of Chippewa River to Alma, Wis	Sept. 27 to Oct. 1	9.00	12.75	2.00	12.75	23.75	120
Minneiska and Chimney Rock	Oct. 1 and 2	1.50	1.50	0.50	....	3.50	17
Rolling Stone	Oct. 2	1.00	1.00	....	....	2.00	15
Winona, Minn	Oct. 3 and 4	4.00	3.00	1.75	3.00	8.75	50
La Crosse, Wis	Oct. 5–7	5.00	4.00	2.00	6.00	11.00	70
Coon Slough and Bad Axe	Oct. 7	1.00	1.00	0.50	....	2.50	6
Prairie du Chien, Wis	Oct. 8–10	7.00	7.00	9.00	7.00	23.00	110
Guttenberg, Iowa, and Cassville, Wis	Oct. 11	1.00	1.00	1.50	....	3.50	20
Dunleith, Ill., and Dubuque, Iowa	Oct. 12–14	5.50	3.50	....	4.00	9.00	100
Fulton, Ill., to Clinton, Iowa	Oct. 15–17	3.25	2.75	2.25	2.00	8.25	150
Burlington, Iowa	Oct. 22–24	3.25	4.00	....	4.00	7.25	100
Keokuk, Iowa	Oct. 26	2.00	1.25	....	1.25	3.25	9
Quincy, Ill	Oct. 27–30	3.5	3.5	7.25	....	14.25	70
Hannibal, Mo	Oct. 30, Nov. 3	3.25	3.5	1.25	3.00	8.00	80
Totals	....	72.50	70.50	37.50	68.50	177.00	1,226

It may be said of these surveys, that while they have no claim to the refined accuracy of geodetic work, they are as good as good plane-table surveys. The party was large, and composed of men of experience in surveying, and possessed of much activity, and everything thought to have a bearing upon the question of bridging, or that gave information about the river, was searched for and obtained if possible. This remark is necessary, because some persons have thought the field was gone over too rapidly to be thorough, but this was not the case. Our subsequent experience enabled us to extend our work, but showed no fault in the conclusions from the survey.

The only portions previously surveyed by engineers with proper means were in the neighborhood of Saint Louis Harbor, at the Des Moines Rapids, and Rock Island Rapids, and a small part of the river near Dubuque. No lines of levels had determined the slope of the river-surface, nor had gauge observations satisfactorily determined the range of surface from low to high water, and the average duration of different stages, except at Saint Louis and Rock Island.

The length of the river between Saint Louis and Saint Paul is about 790 miles as navigated by steamboats. The information previously obtained about this portion of the river was nearly all of the kind obtained by the United States land-surveys. These surveys were made on the two sides of the river from different base-lines, and seldom connected across by triangulation or other measurement. Many islands were not included in these surveys at all. Their imperfections were not appreciated by us at first, and at considerable effort and expense we had copies made from the Land Office plats along both banks of the river.

Letters were also written to all parties known to be interested in building bridges, and to all the principal steamboat companies, and conversations held with every one who would give facts or views in regard to the matter. In this way a number of town plats were secured that aided us somewhat in connecting our surveys with the United States land-surveys.

We thus found ourselves possessed of a large amount of crude topographical information procured by ourselves and others, some of it of recent date, and some of it, in the lower part of the Mississippi, of many years back, specially valuable as enabling us to compare the subsequent changes.

Mapping surveys made in 1866.—After the completion of the field-work, in 1866, the force of assistants was reduced to four—H. C. Long, J. P. Cotton, C. H. Conwell, and Henry Custer. This was made necessary by reason of the small amount of money available for this work. These assistants were employed in preparing the maps of the surveys, working up the notes, and in assisting in the preparation of estimates and reports.

The maps of the surveys were made on a scale of 200 feet to the inch, on Manila paper. Tracings were made of such as were submitted to the department. Sketches of particular localities were reduced to scale of 2 inches to 1 mile, to accompany the preliminary report upon all of the work of 1866 except the bridge investigation dated January 21, 1867, printed as H. Ex. Doc. No. 58, Thirty-ninth Congress, second session. On the 31st of January, 1867, a map on a scale of 100 feet to the inch was sent to the Chief of Engineers, showing location, direction of current, objectionable features, &c., of the railroad-bridge at Clinton, Iowa. On the 4th of February I was called before the Committee on Post-Offices and Post-Roads, Hon. Alexander Ramsey chairman, and gave my views in reference to the Clinton bridge, the substance of which is included in the special part of Chapter V relating to this bridge.

The attempt was made to construct a map of the whole river on a scale of 2 inches to the mile from the data on hand, but it was found so incomplete that the only use of it was to show how much was lacking, and what we must supply.

Surveys made in 1867.—In April and May I attended, as a member, the meeting of the Board of Engineers at Keokuk, to report upon the plan for a canal to avoid the rapids in the Mississippi just above that place. Messrs. Cotton and Conwell accompanied me here, and while performing work connected with the Board, we investigated the river phenomena, getting measures of volume, &c. The Board adjourned to Davenport, Iowa, and there we made similar investigations and measurements, and some additional ones at the Clinton bridge, 34 miles above Davenport. The surveys at Davenport, though limited in extent, proved of value afterward when the construction of the Rock Island bridge was begun in 1869.

On the adjournment of the Board, in May, 1867, I proceeded with Messrs. Cotton and Conwell to Saint Louis. Mr. Cotton set out from this place to supply connections with the United States land-surveys and get such other information as it was practicable to obtain above that city as far as Keokuk. Mr. Conwell went below as far as the mouth of the Ohio, for the same purpose. The high water greatly circumscribed their operations, though valuable results were obtained.

Accompanied by Maj. H. C. Long, civil engineer, I proceeded to examine the wrecking-boats and other vessels that might aid us in improving the Upper Mississippi, and, in doing this, went also to Louisville and Cincinnati. At this last place we saw the suspension bridge, just finished, a monument to the capacity of engineering skill to furnish ample means of crossing a great river without obstructing its navigation.

We all arrived back at Saint Paul about the second week in June, and set about measuring the river volume and preparing to renew our surveys on the Upper Mississippi, and to begin an accurate survey of the Wisconsin River below Portage. The river at that time was too high to make surveys of the low-water river, but presented a favorable opportunity to get its volume in flood stages. Preparations were immediately begun and the work of measuring the volume commenced.

To get at the amount from the Mississippi and Minnesota, a base-line was selected above Minneapolis for the Mississippi, and one above the railroad bridge on the Minnesota, and one at Saint Paul as a check on the other two. Surveys of a portion of the river immediately above and below the discharge sections were made. As it was desirable to make observations at all three places on the same day when practicable, the base near Minneapolis was abandoned, and one selected near Fort Snelling immediately above the mouth of the Minnesota River. These observations were continued, with but few interruptions, until the closing of the river by ice. The manner of conducting these observations and results obtained will form part of a report on improving the navigation between the Falls of Saint Anthony and Rock Island Rapids.

During July, August, and September, a quarter-boat for lodging a surveying party was built at Saint Anthony under direction of C. H. Conwell, civil engineer. This boat was 80 feet in length and 18 feet wide, fitted up to accommodate a party of about 40 men. This boat was not as large by one-half as she should have been for comfort and convenience.

During the latter part of August and the first part of September the river between Meeker's Island and Fort Snelling was surveyed. This was done while the party were regularly making observations for discharge of the Minnesota River, the Mississippi River at Fort Snelling (above the mouth of the Minnesota), and at Saint Paul.

In the flood of July, 1867, the channels about Pike Island underwent great changes. The channel between it and Fort Snelling was nearly filled up, while the other, north of the island, was enlarged. In the latter part of September these channels were resurveyed, the shores meandered, and soundings taken in all of the channels. These soundings were all located by measured angles from each end of a measured base on the shore. The water's surface was referred to permanent bench-marks in the vicinity, and the gauge-reading at Saint Paul noted. These soundings give accurately the condition of the channel at that time.

In the latter part of September the river fell within its banks. Mr. Cotton was then directed to organize a party for continuing the surveys commenced last season. This party consisted of J. P. Cotton, in charge; J. A. Craik and Job Yoak, civil engineers, transitmen; H. P. Farrar, civil engineer, leveler; A. M. Scott, civil engineer, compassman; and H. D. Van Pelt, recorder of soundings; with chainmen, rodmen, axmen, boatmen, and cooks, the party numbering thirty-eight men all told.

Work was commenced near Pig's Eye Island, 3 miles below Saint Paul. This portion of the river had been surveyed in 1866, but in the mean time the bar at the head of the island had been troublesome, and had been reported to be composed in part of loose rocks or bowlders. The survey was made to settle this question, and to see what changes had taken place in the bars of this part of the river. The manner of conducting surveys this year was much the same as that followed by the party of 1866, a transit line being run on each bank, a compass line on the islands, a level line on one bank, and lines of soundings as often as every 500 feet.

The transit lines were run by deflecting from the back sight at each change in the line, this deflection being noted and at the same time the magnetic bearing. The first deflection at the end of the first course was subtracted from or added to the magnetic bearing of the first course, and entered in a column in the note-book marked "corrected course" directly opposite the magnetic bearing of the course. At the next angle point the deflection was noted in its proper column "right" or "left," the "corrected course" of new line figured, and the magnetic bearing of it recorded in its column. The sample below illustrates the way the notes were kept:

Station.	Right deflection.	Left deflection.	Corrected course.	Magnetic course.
5				
+.50		7° 18′	N. 23° 20′ E.	N. 23° 15′ E
4				
3				
+.27	3° 23′		N. 30° 38′ E.	N. 30° 45′ E.
2				
1				
0				N. 27° 15′ E.

By this method any error in reading or recording the deflection angle would be likely to be discovered in time to correct it, and cases of local magnetic disturbance would be detected. This method of keeping notes will generally prevent a careful engineer from making great errors in recording, and enable him to detect at the time an error in reading.

These transit lines were connected as often as each half mile by triangulation, each transitman setting up a signal at a station on his line which the other was instructed to locate by taking angles to from two or more angle points on his line.

The transitmen were charged with setting blazed stakes or other signals at the water's edge at each 500 feet of their line, or oftener in special localities, and note the station and distance from the line in their note-book; also write the number of the station on the stake or signal. The signals set by either transitman were marked with his initials, and all set up on a continuous survey were numbered serially. Each transitman was furnished with a boat and boatmen whose duties were to transfer the party from the quarter-boat to the work and back, to carry them across sloughs, and to set up signals on the head and foot of islands and sand bars.

The compassman, in meandering the islands, commenced at the signal set up by the transitman, or, in case the transit lines had not reached this part of the river, he set up such signals at his starting point, and prominent points along the line to be located by them.

The assistant in charge of the sounding party was instructed to sound between all the sounding stakes, and always to run a line of soundings across the head and foot of each island chute, bayou, or slough. A line of levels was run on one bank, and the height of the banks of main shore and islands noted. Cross-sections of the valley were run as frequently as could be done, and keep the main line along with general survey of the river. The assistant in charge, Mr. Cotton, was continually employed in the field directing the parties, and especially looking after the hydrography of the river, staking out and locating submerged bars, noting the prominent points supposed to direct the currents, and sketching such sloughs and bayous as were not deemed of sufficient importance to require meandering.

For the first two weeks after taking the field the lines run were roughly plotted in the evening to see that each principal of party was performing the duties required of him in such manner as would insure satisfactory results in the map of the survey. The plotting of the notes brought forcibly to the minds of these assistants, who had heretofore been employed on railroad surveys only, the importance of particular attention to details in their topographical notes, such as the accurate delineation of all rocky spits that might act as wing-dams in their influence upon direction of the current at certain stages; the location of small tributaries which, in floods, might bring in large quantities of sand, gravel, &c. The cross-section of these, at the time of survey and when bank-full, should always be noted.

Having made the survey in the vicinity of Pig's Eye Island, as previously stated, the boat was allowed to float down to Red Rock, the termination of the continuous survey from Fort Snelling made in 1866, where the regular survey was commenced on the 3d of October, the gauge at Saint Paul reading 4.2 feet. From this point to Hastings, Minn., a continuous survey of the main river was made; all of the principal islands were meandered; a level-line run, and three partial cross-sections of the valley made; observations for discharge of the principal sloughs were made, and a set of observations for volume of the whole river at Hastings.

The quarter-boat was managed by two boatmen. As soon as the parties had gone out to work in the morning, if the wind did not blow, they pushed the boat out into the current and let her float down river about as far as the parties would be likely to get by night. This was always done early in the morning, because at that time it was usually calm, while later in the day the wind generally blew from the south so strong as to make the moving of the boat an impossibility without motive power other than the current.

The survey to Hastings was completed on the 14th of October, and on the 15th the quarter-boat was taken in tow by the United States steamer Montana and left at the mouth of the Cannon River, where a survey of three miles of river was made, which included the forking of the river into two of the three channels by which it enters Lake Pepin.

On the 17th October the quarter-boat was towed to Wabasha by the *Montana*, where the survey was again commenced.

This embraced an instrumental survey of the larger and a reconnaissance of the smaller sloughs in the delta of the Chippewa River, extending up this river 14½ miles to where the river is all in one channel. The Mississippi River survey was repeated over parts surveyed in 1866, for the sake of noting changes, and it was continued to Winona, Minn., a distance of about 35 miles along the valley (a much greater length measured along the river). It embraced the whole valley from bluff to bluff, often 5 miles in width. All of the sloughs that are ever navigated by small steamboats or rafts were meandered and sounded out, and most of those which were too small for either were sketched.

The surveying of the sloughs and side-channels was done at a great outlay of time and labor, as some of them were as much as 5 miles in length, requiring a journey by boats of this distance morning and evening when at work near the middle of the longest of them. While surveying this part of the river it became necessary to organize extra sounding parties, as it was impossible for one party to sound out all of the channels and keep along with the other parties. In surveying the

10 miles of river immediately below Alma two full parties for sounding were constantly employed. This was frequently done, the leveler and his party, or one of the transit parties, making a second sounding party. Throughout the whole survey the assistants were called upon for any duty connected with the work, such as locating submerged bars, making observations for discharge, making cross-sections of the valley, taking heights of bluffs, &c. The survey to Winona was finished on the 8th day of November, connecting with the survey made at that place in 1866.

The next point at which it was deemed desirable to have detailed surveys was at Coon Slough, some 35 miles below Winona, measured along the valley. We tried to get one of the steamers to tow the quarter-boat down, but it being near the close of the season, and plenty of freight offering, none were found willing to be bothered with such a tow. After waiting two days trying to get towed, Mr. Cotton concluded to try to float down. As the wind almost invariably blows upstream during the day at this season, it had to be done by night if at all. The party was accordingly divided into three reliefs, two boats were manned by a relief, and with a line to the quarter-boat started on the evening of November 11 as soon as the wind went down sufficiently to permit it.

This was continued by each relief working two hours and resting four, through the night. At the upper mouth of Black River they were met by the south wind, which prevented further progress. The day was spent in making a survey of 4½ miles of the river at this point. As soon as the wind went down in the evening the boat was again started on her journey, this time by "cordelling," when the nature of the shore would permit, and by towing with skiffs when the shore was not suitable for "cordelling." Brownsville, at the head of Coon Slough and Raft Channel, was reached on the following day about noon, and the survey commenced in the afternoon of November 13.

The two principal channels were surveyed, and all of the smaller ones either surveyed or sketched. The survey of this section to Genoa, or Bad Axe, a distance of about 13 miles, was completed on the 19th day of November, and the boat towed to Lansing in that night by means of skiffs, in the manner described above. A survey of 1½ miles was made at this point, when, on account of the lateness of the season, it was deemed best to discharge the parties and lay the boat up for the winter. This was accordingly done on the 22d day of November, the party having been in the field since the 1st of October. During this time not a day was lost on account of bad weather, field-work being carried on every day except when moving from point to point.

The surveying party, under direction of Maj. C. R. Suter, Corps of Engineers, on the Wisconsin River, on reaching the Mississippi were directed to drop down to Clayton and make a survey of the Mississippi, so as to include the two parts known as the Cassville and Guttenber channels and their connections. This survey was made between the dates of October 7 and 12, and embraced a distance of 9½ miles measured along the valley. This surveying party was conducted in the same manner as that on the Mississippi already described.

In addition to these surveys, special examinations were made by myself and assistants, Conwell and Brunson, in the delta of the Chippewa; in the lower part of the Cannon River; in various sloughs and chutes in parts of the river not embraced in the detailed surveys, and observations for volume of the Mississippi River and sloughs, and of some of the tributaries.

The following table exhibits the results in miles run, &c., of the surveys of this season:

Location.	Date. From—	Date. To—	Transit.	Compass.	Level.	Miles of river.
Pig's Eye	Oct. 2	Oct. 2	6	......	......	2
Red Rock to Hastings	Oct. 3	Oct. 15	30¾	16	20	17
Mouth of Cannon River	Oct. 17	Oct. 17	3¾	2	3	2
Alma	Oct. 18	Nov. 8	77¼	35¼	46	36
Black River	Nov. 12	Nov. 12	4	2¼	......	4
Coon Slough	Nov. 13	Nov. 19	21½	11½	16½	10
Lansing	Nov. 22	Nov. 22	1¼	......	½	1½
Meeker's Island to mouth of Minnesota River	Aug. 26	Sept. 12	9	8¾	10	8
Guttenberg and Cassville	Oct. 8	Oct. 12	20½	18	9½	9½
Total			174	93¾	105½	90

In June, 1868, I was directed to examine the railroad bridge across the Ohio River at Steubenville, Ohio. My report upon the result of this examination was submitted June 29, 1868. With it was a

Draught of provisions required to secure to navigation the full benefit of the passage way through bridges across navigable streams, the least width of which passage-way is fixed by law,

and an estimate of cost of bridge, 1,700 feet long,

With continuous spans, one of them 500 feet in the clear, two of them 300 feet in the clear.

This report, draught of law, and estimate were published as part of report of Senate committee No. 168, Fortieth Congress, second session.

In the succeeding annual report of the operations for the fiscal year ending June 30, 1868, the results of the surveys are partially given and a statement of the progress made in completing the maps.

Surveys in 1868.—In October, 1868, Mr. Cotton, who had been employed with assistants since the close of last season in working up the notes of his work in 1867, was directed to organize a party and make special surveys at points along the river where surveys had been made before, to ascertain what changes, if any, had taken place, and also at bridges and proposed sites for bridges.

The party as made up consisted of J. P. Cotton, civil engineer, W. Weston, civil engineer, A. M. Scott, civil engineer, and 2 rodmen, 4 boatmen, and 1 cook. They were provided with 3 skiffs and 3 wall-tents.

Work was commenced in the vicinity of the mouth of the Minnesota on the 12th day of October. The volume of the Minnesota and of the Mississippi above and below its mouth was measured. A full set of current observations at the bridge of the Milwaukee and Saint Paul Railway over the Minnesota, and soundings above and below it, were made.

In making surveys and observations for direction of current, either at bridges or otherwise, this season, the following method was pursued. A base line as long as the location would admit was selected, and its length carefully measured. A transit was set up at each end and the angles to all prominent points in the vicinity measured; if at a bridge, a rodman was directed to hold a flag-staff at the middle of each pier, the angle to this staff being simultaneously measured from each end of the base by the transitmen. When the weather was favorable the party proceeded at once on their arrival at a bridge to make observations for direction of current so that no delay should occur on account of windy weather. All soundings made during this survey were located by triangulation. The level of the water's surface was referred to permanent marks, so that comparisons can be made in the future.

The piers of the bridges, size, height, and shape were carefully measured, and also the principal parts of the superstructure.

Having finished the examinations at this point, tents were struck and the party proceeded to the Milwaukee and Saint Paul bridge (railway) over the Mississippi 2 miles above Saint Paul. Here they went into camp and spent two days in sounding, making current observations, and measuring the piers and running levels to enable them to construct a cross-section along the line of the axis of the bridge.

The next examination was at the Saint Paul highway bridge. Here current observations were made.

From this point to Wabasha, Minn., the party with skiffs, tents, instruments, &c., went by steamer.

From Wabasha to Alma, a distance of 3½ miles, soundings were taken on all of the bars shown by survey of 1866 or 1867, and on those where navigation had been obstructed during the season of 1868. Special pains were taken to locate the *crossings* on bars where the scraper dredge-boats had been employed during the season. The surface of the water was referred to the bench-marks of 1867 and observations made in all of the island chutes for discharge as nearly as practicable on the sections used in 1867 for this purpose.

From Alma the party went in skiffs to Rolling Stone Bars (about 3 miles above Fountain City). Here a survey of the bars at the head of Rolling Stone Slough and Horse Shoe Bend was made; the crest lines carefully defined by a line of soundings along them, and soundings above and below them. Observations were made for discharge of all the side channels.

The next point at which examinations and surveys were made was at Winona, Minn., where preparations were being made to erect a railway bridge. The survey here consisted in locating soundings in all of the channels, observations for volume of the east channel where the bridge had been located, and a cross-section of the intervening island, and of the main or west channel.

The next point at which it was proposed to make surveys was at Dubuque, Iowa, so far below that it was economy to go by steamer. Accordingly, skiffs, tents, and party were transferred by steamer, reaching Dubuque on the 28th day of October, when tents were pitched, and the survey commenced. This survey embraced, in addition to the current observations, soundings, and measurements at and about the railway-bridge in process of construction at this point, and a survey of the harbor of Dubuque, which had been for several years becoming more difficult of access in low-water, by reason of a sand-bar extending along the whole front of the town. This survey was completed November 1. The rest of the surveys to be made being at or near towns, it was deemed cheaper and more expeditious to send the tents back to Saint Paul, and find board for the party at points where examinations were to be made.

The next point where examinations were made was the Clinton Bridge. This had been surveyed in 1866 and 1867, so that it was not deemed necessary to do more than make a few observations for direction of current, and a survey of that part of the bridge over the east channel which was being rebuilt. The survey at this place was completed on November 6.

The next point at which surveys were required was at Rock Island, to which place the party went by steamer. Here a survey of the bridge and current observations above and below were made. The work was completed on the 11th day of November.

From this point the party went by steamer to Burlington, Iowa, and made a survey of the railroad bridge and a full set of current-observations. This bridge had been built since the survey of 1866. A full survey of the bridge and of the river above and below it was made; also, a complete set of current-observations above and below the bridge. The survey at this point was completed on the 14th of November, and the party went to Fort Madison, Iowa, in skiffs that evening.

On the following morning they went to Keokuk, Iowa, and took steamer to Quincy, Ill. A survey was made of the railroad bridge just completed at this place, and a full set of current-observations was taken above and below the bridge.

From this place the party, with skiffs, &c., went by steamer to Alton, Ill., reaching there on the 19th instant. The survey was commenced on the following morning at Hop Hollow, about 2 miles above Alton. From this point a line was run on one bank and part of the distance on both down to and including the mouth of the Missouri River, connecting there with the survey made by Col. W. E. Merrill, Corps of Engineers, for Saint Louis Harbor. Soundings were located throughout the whole of this distance of 7½ miles. Observations were made for the discharge of the main river, and of the sloughs back of the sand-bar opposite Alton and west of Ellis Island. Soundings were also made in these sloughs with special reference to estimating the cost of closing one of them as a means of improving the navigation in the main channel of the river along the levee-front of Alton.

At the mouth of the Missouri River, special observations were made for the direction of current where the two rivers unite. The great length of base line used here made the *calling* of "time" impracticable.

To insure as near simultaneous reading of the angle as possible, the time-keeper was stationed close to one of the observers with a flag. Another man was stationed by the other observer, whose duty it was to watch the motions of the time-keeper, and inform the observer. When a float was started from the boat, the time-keeper called attention to it by raising his flag 5 seconds before the even half-minute; at the even half-minute he dropped the flag and called "*time*" to the observer near him. These motions would be seen and communicated by the attendant to the observer at the other end of the base. A set of signals were agreed upon between the party in the boats and the observers before commencing, so that all movements by either party were readily communicated to the others, thus preventing mistakes and loss of time, an important item when working in a river where the current ran 4 miles per hour and the points of observation three-fourths mile apart.

This survey was completed on the 5th day of December, the boats stored at Alton, and the party disbanded, the assistants returning to Saint Paul with instruments and note-books, to prepare the maps and diagrams.

Late in the winter, after much delay, a current-meter was received at Saint Paul, and some interesting velocity-observations under the ice at different depths were obtained.

In October of this year, I was appointed member of a special commission, under the Interior Department, to report upon the condition of the

Pacific railroads. This duty was finally made to embrace all Pacific Railroads and branches, and occupied all my time until July, 1869.

Surveys in 1869.—In July, 1869, I was ordered to proceed to Rock Island, Ill., and relieved Col. T. J. Rodman, United States Ordnance Corps, of the charge of the construction of the new government bridge to connect Rock Island with Davenport, Iowa.

Before fixing upon the final plan and location, it was necessary to have a much more extensive map of soundings and current-observations for direction and velocity than had as yet been made, and I directed Mr. Cotton to make these surveys. The quarter-boat used on previous surveys was towed down and a party put on board, and the work commenced on the 30th of July.

The river at the time was quite high and the current so strong that a boat could not be rowed against it. To sound in a desired locality, it was necessary to go with the boat some distance above, keeping near the shore, and then reach the spot by steering out obliquely with the current. Having arrived at a point in the stream directly above the desired location, the boat was anchored, and then allowed to drop down by paying out the anchor-line. In this way the whole river was sounded over for a distance of several hundred feet above and below the proposed bridge location. The bottom of the river being rock, with occasional "pots" or holes in it, a great many soundings were necessary to properly delineate it. Within a distance of one-half mile upward of 8,000 soundings were taken before a satisfactory counter-map of the bottom could be made. Several days were also spent in making current-observations.

Upon the completion of this survey and map, Mr. Cotton, with Assistants H. A. Bentley and L. S. Chase, was directed to make observations at the *Burlington*, *Keokuk*, *Quincy*, and *Dubuque Bridges*, the object being to get the direction of the current at the high stage of water then prevailing, and which opportunity had not occurred before. The annual report of the Chief of Engineers of our operations during the fiscal year ending June 30, 1869, gives the condition of the Mississippi maps and data at that date.

Circumstances under which maps and report were prepared.—Much progress was made during the winter of 1869–'70 in plotting the surveys in pencil, but ill health prevented my doing any hard work after the 1st of January.

During the month of February, 1870, the stations of a number of officers of the Engineer Corps were changed by orders, and I was assigned to the charge of the Lake Surveys, one of the duties of the highest honor and importance under our management. But at the time my health was so enfeebled that, at my own request, I was relieved from it. As the same orders had assigned Colonel Macomb to the charge of my duties, I was given the station at Newport, R. I. It should be noted here that although I had made considerable surveys and measurements on the Mississippi, I had no opportunity to complete the report. From October, 1868, to June, 1869, I had been away on the Pacific Railroad; from June to October, I was closely occupied in starting the work on the Rock Island bridge; during October and November, I was upon the Wisconsin River projects; and in December, in arranging for work upon the large amount of field work and notes that were to be elaborated. Among other matters not named was a detailed survey of the battle-field of Gettysburg. These things are given fully in the first chapter of my report on the Wisconsin River.

I was authorized to take all my unfinished work on the maps and reports with me to Newport, and complete them there.

In the summer of 1870 I had all I could do in performing the duties of my new station.

On October 18, 1870, I was appointed a member of a Board of Engineers to examine the bridges on the Ohio River in accordance with section 5 of the act making appropriations for the improvement of rivers and harbors, approved July 11, 1870. The partial reports of this Board were made December 12, 1870, and February 7, 1871, and the final report April 19, 1871, all of which were printed in the Chief of Engineers' Report for 1871, pp. 397 to 457 inclusive.

By Special Orders No. 106, dated Headquarters Corps of Engineers, September 29, 1870, a Board of Engineers, of which I was the senior member, was ordered to convene at Buffalo, N. Y., to examine the plan and location of the international bridge over the Niagara River at that place. The report of this Board was published in Chief of Engineers' Report for 1871, pp. 219, 220, 221.

On the completion of the duties on these boards in the spring of 1871, the very large amount of local work at the Newport district required undivided attention during the whole outdoor working season.

I was again a member of an Engineer Board, reconvened by Special Orders No. 108, Headquarters Corps of Engineers, dated August 3, 1871, to consider the plans for the modification of the Cincinnati and Newport bridge, as submitted by Thomas A. Scott, esq., president of the Pennsylvania Railroad Company.

In August, 1871, the project of bridging the Missouri at Saint Joseph, prepared by the chief engineer, Mr. E. D. Mason, was submitted to me for remarks. My reply was dated August 25, 1871. But we got at work with a very large office force in the autumn and winter, and by February had essentially completed all the original maps and the compilation of the map on a scale of 2 inches to the mile, and sent tracings of them to Washington; but though many parts of the several reports were prepared, there was not time enough to complete any final report. I had to at once attend as a member of a Board on the harbor of Saint Louis (see Annual Report for 1872); and another month was used up as a witness against the contractor for the Rock Island bridge masonry.

March 27, 1872, I made a report upon Senate bill 845, of Congress then in session, authorizing an additional bridge across the Mississippi River at Quincy, Ill.

June 29, 1872, I submitted a report upon the bridging of the Mississippi River at La Crosse, Wis.—(See La Crosse bridge, in Chapter III.)

Duties at Newport occupied all the outdoor working season. The winter of 1872–'73 was passed in study of works on river and canal improvements and in arranging and elaborating the data from the Mississippi surveys for the final reports. The general map on scale of 6 miles to the inch was partially finished.

January 16, 1873, Senate bill 1302, authorizing the construction of a bridge across the Mississippi River at Saint Louis, was sent to me for report with recommendations and suggestions. My report upon this, dated January 21, was submitted.

January 25, 1873, a substitute for Senate bill 1302 was sent me for report. My report upon this was transmitted January 28, 1873.

May 21, 1873, the plan of a proposed bridge across the Mississippi River at Louisiana, Mo., authorized by act approved March 3, 1871, was submitted to me for investigation and report. My report was forwarded under date of May 31, 1873.

During 1873 I was president of a Board of Engineers to report upon bridging the navigable channels between Lakes Huron and Michigan (see Annual Report for 1874, pp. 947–1051); also member of a Board of Engineers to report upon the obstruction to navigation caused by the bridge at Saint Louis (see Chapter III); also a member of the Board on the Fort Saint Philip Canal project.

The first part of 1874 was a very busy period at my Newport station. In June, 1874, I was made president of the commission on the protection of the alluvial regions of the Mississippi. This commission exacted a good deal of hard labor, but the final report on the Minnesota River was completed and the last of the Mississippi bridge surveys was finished and copies sent to Washington.

No other work upon the Mississippi River bridges was done until after the rendition of my final report on the Wisconsin River, November 26, 1875, and the attempt was then made in the beginning of 1876 to complete the final report on bridges, but there had been so many of the bridges completed since of surveys in 1869 that it was thought desirable to obtain authority and money to make surveys of them in the season of 1876. These were given by the Chief of Engineers out of available funds, and surveys were accordingly made of the bridges at Hastings, Winona, La Crosse, Prairie du Chien, Keokuk, Hannibal, and Louisiana. The maps and tracings were completed in January, 1877.

During the season of 1876 I was also made a member of the Board of Engineers to consider the question of placing sheer-booms at the piers of the bridges on the Mississippi to facilitate the passage of rafts. All the maps obtained by me were placed at the use of the Board, which completed its report February 2, 1877. (See Annual Report for 1877.)

After the duty of this Board was over, the preparation of the maps for publication was begun and continued until the outdoor work stopped us. In the autumn the opportunity was presented of taking up this final report with a prospect of finishing it. There was only one interruption given, and that was in the reconvening of the Board of Engineers on the Ohio River bridges at Evansville, which caused about a month's delay. The office-work on the final report has been pursued without a day's intermission (when not interrupted by local duties) through the winter and down to the date transmitting it.

While conducting the surveys and other work in a field as little developed as this was, we gathered everything we could, so that if it could aid us in any way, directly or indirectly, we might have it at our command. While this was going on, we had necessarily to keep our office maps, &c., in an unfinished state, so that they might be open at all times to additions and revisions; but, at the same time, the field-work was as rapidly as possible worked up according to its nature and plotted on maps or assembled in tabular form. Thus we passed out of that stage when reference to note-books was necessary, while as yet the maps designed for final presentation were left in pencil or were finished as special representatives. A great deal of the practical results were thus at once available for immediate use on the improvements and questions concerning bridging.

The maps constructed were on several scales and on separate sheets, of which the following is a detailed description:

LIST AND DESCRIPTION OF ORIGINAL MAPS.

The maps of the river constructed from our surveys are on several scales and on separate sheets. That portion of the river from the level above the Falls of Saint Anthony to the outlet of Lake Saint Croix was all surveyed, and has been mapped on ten successive sheets, averaging in length about 10 feet each, on a scale of 200 feet to the inch.

Portions of the river were more than once surveyed to measure changes going on, and at such places there is more than one map to be duly described. On these maps the transit lines and triangulation lines are shown; places of making velocity observations and volume are given; sections along and across the river and valley, topography, depths of water, levels of water surface and bank, connections with United States land surveys, and all the information that could be obtained, is shown.

The following is a detailed description of these maps, viz:

Sheet No. 1 begins 2½ miles above the Falls of Saint Anthony and extends down about 6½ miles.

Most of the survey was made in 1867. The part from the falls to Meeker's Island, about 2¾ miles, as first surveyed, was sent to Washington with the report of my assistant, Mr. Frank Cook, civil engineer, dated December 31, 1866, on a scale of 200 feet to an inch. It was made with a view to an improvement by dam and lock at Meeker's Island.

Subsequently, in 1869, some additional soundings, not shown on Cook's map, were made, of which a report appears in the Annual Report of the Chief of Engineers, 1870, p. 275. Tracings of this sheet sent to the Chief of Engineers February 14, 1872.

Sheet No. 2 extends down to Fort Snelling, including the junction of the Minnehaha, a distance of about 4 miles along the river, surveyed in 1867. A copy of this map from Minnehaha Creek down to Fort Snelling, a distance of about 2 miles, was furnished Lieut. Thomas Turtle, Corps of Engineers, in the spring of 1870, and used by him in establishing the boundaries of the Fort Snelling reservation. The section of the river shown on the lower end of the map was much used by us in measuring volumes of discharge in the Mississippi and Minnesota Rivers. A tracing of this map was sent to the Chief of Engineers February 14, 1872.

Sheet No. 3 extends from Fort Snelling downward about 4½ miles. This was surveyed in 1866. It shows Pike Island at its upper end, and the railroad bridge across the mouth of the Minnesota River. At its lower end is the first railroad bridge across the Mississippi. A tracing of this map was sent to the Chief of Engineers February 14, 1872. This sheet is accompanied by three other sheets, designated as No. 3′, No. 3″, No. 3‴.

No. 3′ is a map, on the same scale, of a resurvey of Pike Island, made in 1867, during the low-water which succeeded the summer floods, which had, for the first time on record, closed the channel between the Mississippi and the Minnesota at the west end of the island. The river opened this again in the succeeding flood. A tracing of this was sent to the Chief of Engineers March 9, 1872.

No. 3″ is a special map of the railroad draw-bridge across the mouth of the Minnesota River, on a scale of 100 feet to an inch; the vertical scale of the profile is 10 feet to an inch. It shows the observations, giving direction and velocity of current, made in 1868. Tracing of this sent to Chief of Engineers December 2, 1874.

No. 3‴ shows the railroad draw-bridge across the Mississippi, from surveys in 1868, on the same scales and in the same manner as described of No. 3″. A tracing of this was sent to the Chief of Engineers December 2, 1874. This tracing was, at my request, returned to me January 20, 1877, and additional current-observations, made under direction of

Maj. F. U. Farquhar, Corps of Engineers, added. This was returned to the Chief of Engineers February 23, 1877.

Sheet No. 4 includes Saint Paul, where extensive current-observations were made, and the high bridge at this place; it extends 4½ miles along the river, it also includes part of Frenchman's Bar. This survey was made in 1866. Tracing of this sheet was sent to the Chief of Engineers February 14, 1872.

Sheet No. 4′ repeats the portion of the river near the bridge on a scale of 100 feet to an inch and vertical scale of profile 10 feet to an inch. Current-measurements for direction and velocity are shown; also detailed drawing of a principal pier. The river section at this bridge shows changes at different dates, proving that when encroached upon in one part it enlarged at another. Tracing of Sheet No. 4′ was sent to the Chief of Engineers December 2, 1874. This tracing was, at my request, returned to me January 20, 1877, and additional current-observations. made in 1876, under direction of Maj. F. U. Farquhar, Corps of Engineers, added. This was returned to the Chief of Engineers February 23, 1877.

Sheet No. 5 extends from Frenchman's Bar to Red Rock, a distance of about 5 miles. It was surveyed in 1866. It includes part of Frenchman's Bar, the Pig's Eye Bars, the Kaposia Bar, and Upper Red Rock Bar. A tracing of this sheet was sent to the Chief of Engineers February 14, 1872.

No. 5′ is a resurvey, made in 1867, of Lower Frenchman's, Upper and Lower Pig's Eye, and Kaposia Bars, on same scale as the other. Tracing of this was sent to the Chief of Engineers March 9, 1872.

Sheet No. 6 extends about 4½ miles along the river, and includes Lower Red Rock Bar and Newport Bar. It was surveyed in 1867. Tracing was sent to the Chief of Engineers February 14, 1872.

Sheet No. 7 extends 5 miles along the river. It includes Robinson's Bar, Pine Bend, and nearly all of Gray Cloud Island. It was surveyed in 1867. Tracing was sent to the Chief of Engineers February 14, 1872.

Sheet No. 8 extends about 5½ miles along the river, and terminates at Nininger. It shows Upper and Lower Gray Cloud Island Bars, and Upper and Lower Nininger Bars. The survey was made in 1867. A tracing was sent to the Chief of Engineers February 14, 1872. Scale of map, 200 feet to the inch.

Sheet No. 9 extends about 4½ miles along the river from Nininger to and including Hastings, Minn., where a bridge had been authorized by the legislature of Minnesota. This survey was made in 1867. A tracing of this map was sent to the Chief of Engineers February 14, 1872. Scale of map, 200 feet to 1 inch.

Sheet No. 10 extends about 5 miles along the river, and includes Hastings, Minn., and Prescott, Wis., also the outlet of Lake Saint Croix. On the lower part of this sheet Prescott Island is shown; this island, at time of low-water, divides the river into two nearly equal channels, in which there is usually more or less trouble to navigation. It has been proposed to close one of these channels by a dam. This survey was made in 1866. A tracing of this map was sent to the Chief of Engineers February 14, 1872. Scale of map, 200 feet to 1 inch.

Sheet No. 10′ is a map of about 1 mile of river at Hastings, Minn., including the railway draw-bridge and approaches. It shows direction and velocity of current, general form of piers, guard-rests, trestles, &c. Tracing of this sheet was sent to the Chief of Engineers January 19, 1877. Scale of sheet, 100 feet to the inch; vertical scale of profile and section, 10 feet to the inch.

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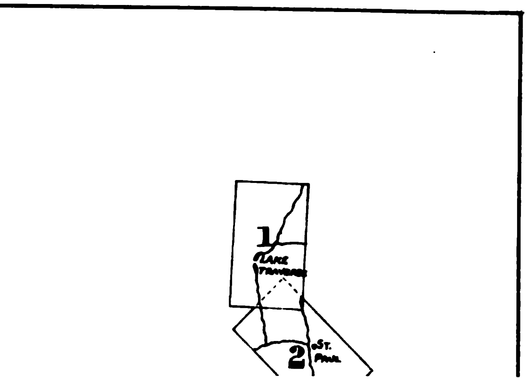


Saint Clair County, Illinois. J. H. Holmes, 1863.

Chester, Ill. Jos. Noel, 1857.

Cairo, Ill. H. C. Long, C. E., 1850.

Cairo, Ill., November, 1855.

United States Land Surveys along the Mississippi River, in Missouri.

Tracing of a portion of Hannibal, Mo. With United States land survey connection, 1867.

Tracing of Hannibal Bridge, 1876 (showing railroad approaches to bridge), by division engineer of T. W. W. R. R.

Louisiana, Pike County, Missouri. John B. Woods, city engineer, 1866.

Tracing of the bridge site at Louisiana, Mo. (with contours of bottom of river), by E. L. Corthel, chief engineer.

Lincoln County, Missouri, by A. R. Finley, published by E. J. Ellis, 1860.

Tracing of the mouth of Missouri River. Survey for city of Saint Louis, by Col. W. E. Merrill, in 1868–'69.

Tracing of the Mississippi at mouth of the Missouri River, showing banks in 1861 and 1868, made for Saint Louis, by J. G. Joyce & Bischoff.

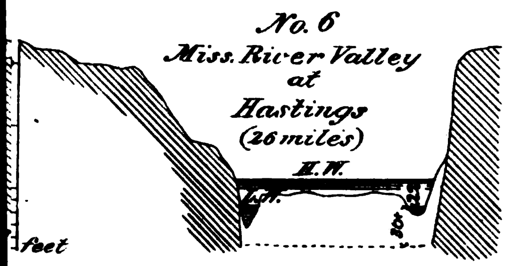
Saint Louis and Saint Charles Counties, Missouri; Madison and Saint Clair Counties, Illinois. L. Gast and Bro., Saint Louis, Mo., 1851.

Saint Louis, Mo. Jules Hutawa, Saint Louis, Mo.

Wolf Island, in Mississippi River, near Columbus, with calculations of quantity of water in each channel in 1843.

Tracings of Swamp Lands in Missouri and Northeastern Arkansas.

Diagram 3.



Abstract of appropriations made for improving Superior Harbor, Wisconsin, showing how expended or to be expended.

Appropriations.	Construction and repairs of piers.	Dredging.	Total.
By act approved March 3, 1867	$63, 000 00	....	$63, 000 00
Allotted from act approved April 10, 1869	45, 000 00	....	45, 000 00
Allotted from act approved July 7, 1870	40, 000 00	....	40, 000 00
Allotted from act approved March 3, 1871	60, 000 00	....	60, 000 00
Allotted from act approved June 10, 1872	50, 000 00	....	50, 000 00
Allotted from act approved March 3, 1873	41, 322 64	$22, 628 16	63, 950 80
Allotted from appropriation "repairs of harbors on the northern lakes"	*5, 433 00	....	5, 433 00
By act approved August 14, 1876	*3, 000 00	....	3, 000 00
By act approved June 18, 1878	*3, 000 00	....	3, 000 00
Total	310, 755 64	22, 628 16	333, 383 80

*Used for repairs and beach protections, and not included in original estimates.

Original estimate for construction of piers	$309, 716 00
Original estimate for dredging	25, 000 00
Total	334, 716 00

Diagram 4.

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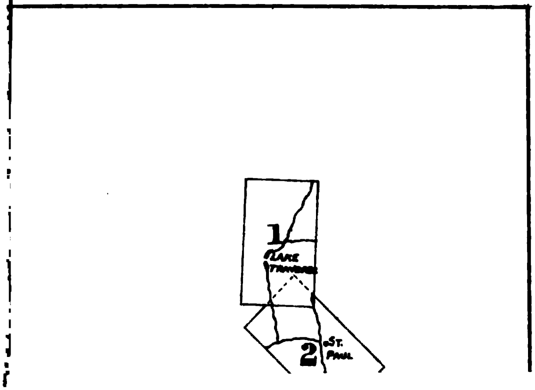

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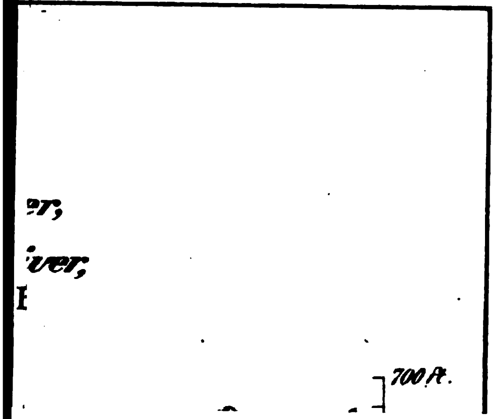

Diagram 3.

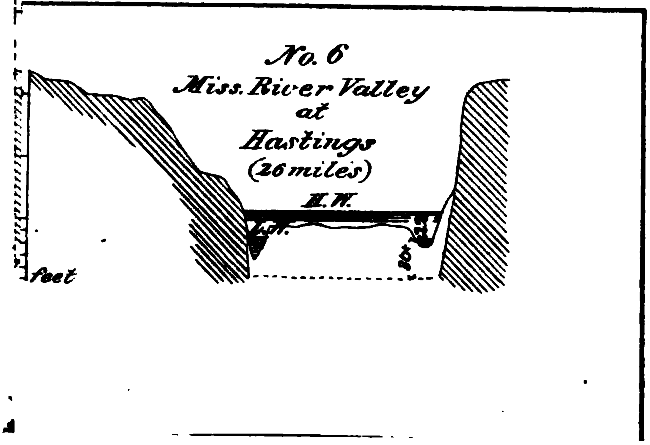

Diagram 4.

Diagram 5.

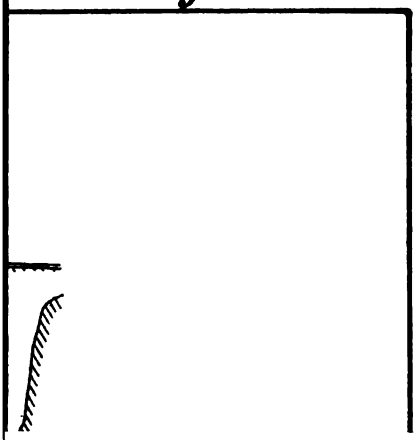

Diagram 6.

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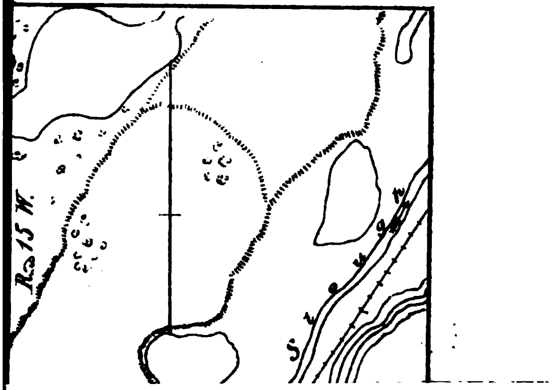
Diagram 7.



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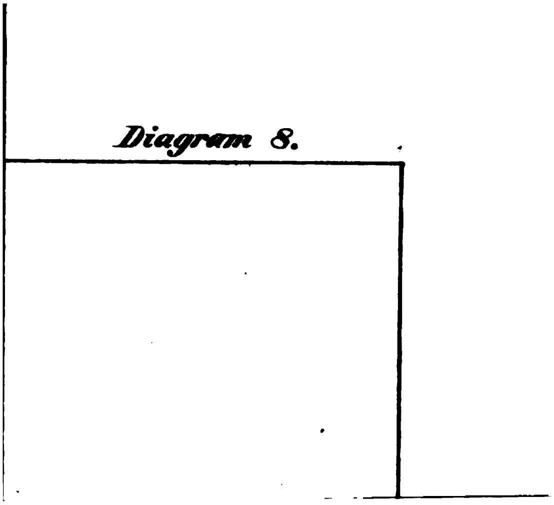


Diagram 9.

Diagram 10.

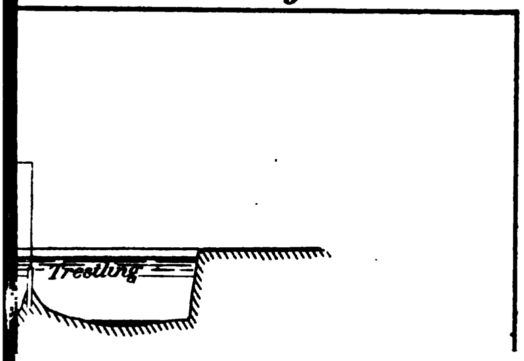


Diagram 11.

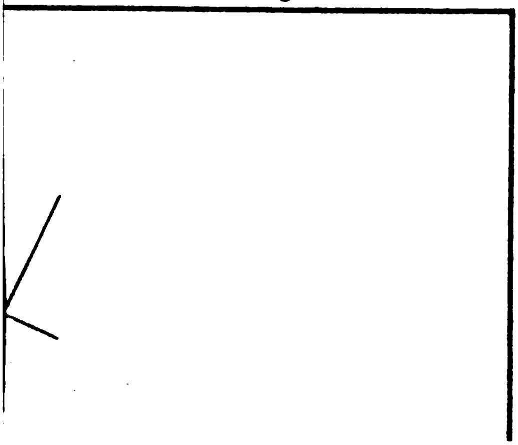
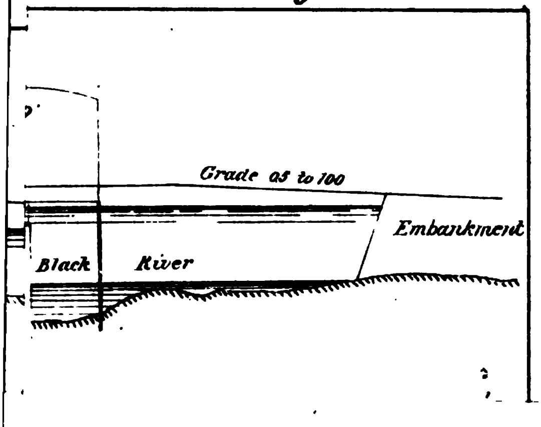


Diagram 12.



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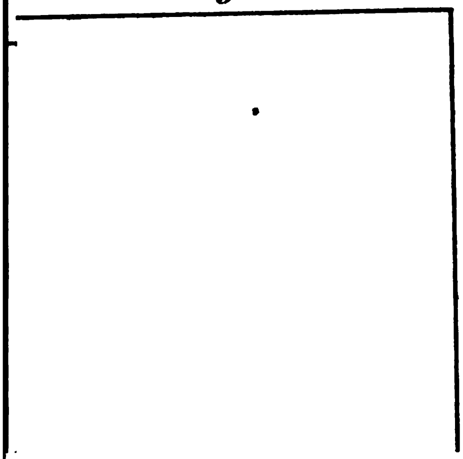

Diagram 14.

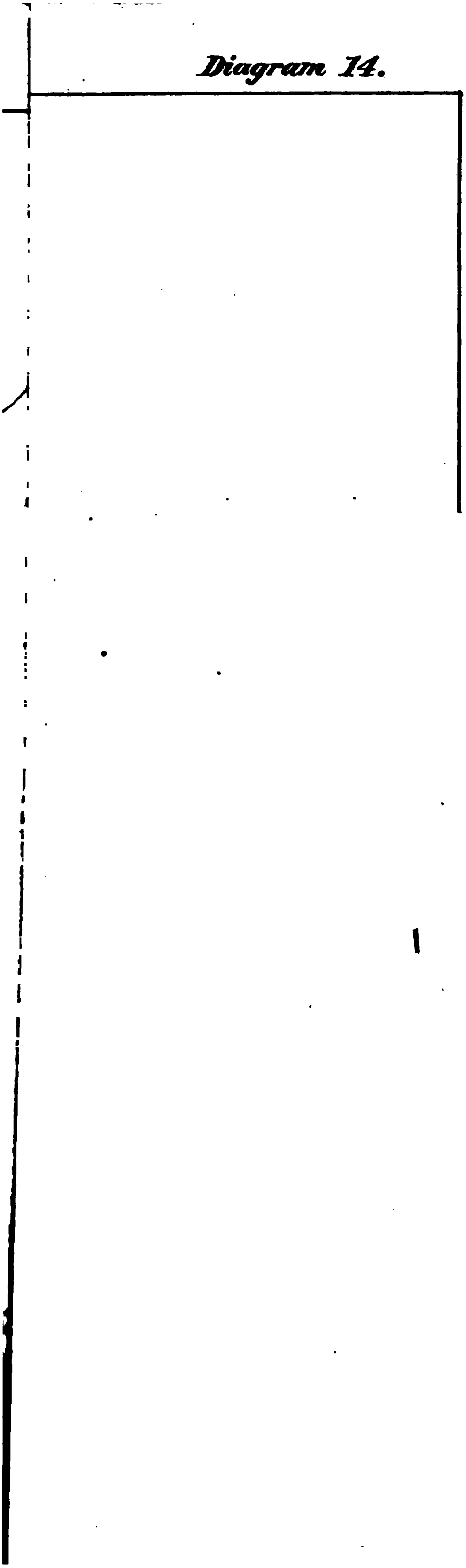

Diagram 15.

Diagram 16.

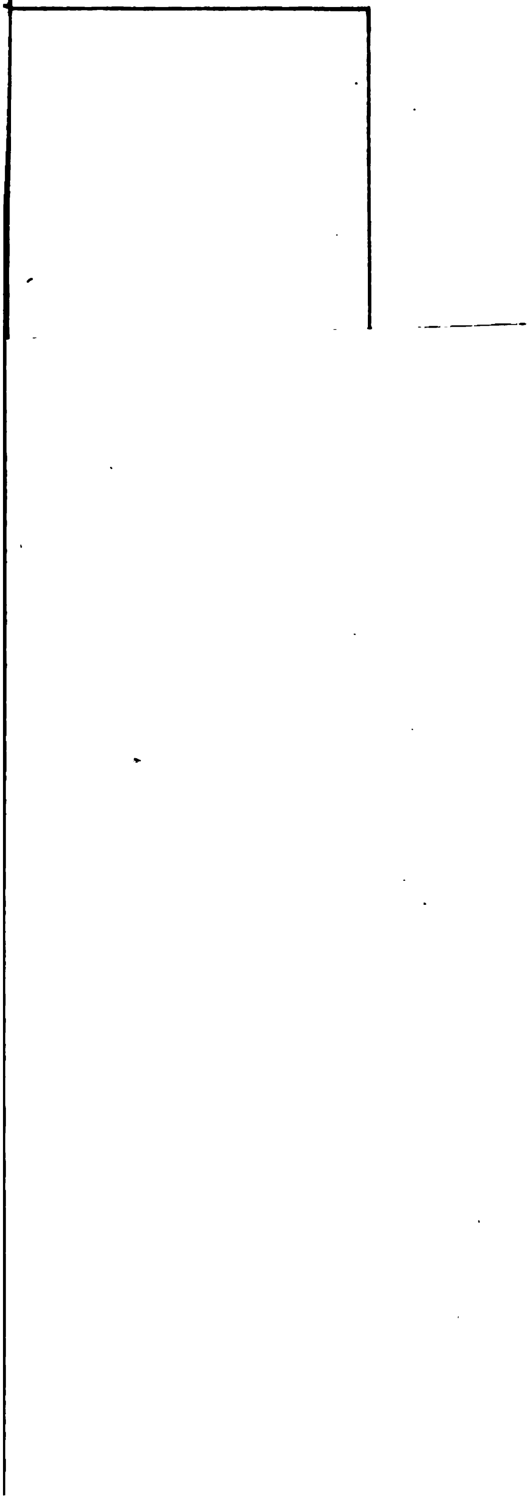

Diagram 17.

Diagram 18.

Diagram 19.

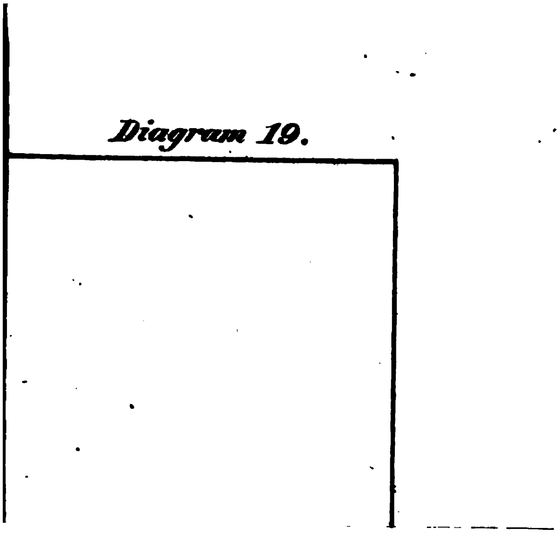

Diagram 20.

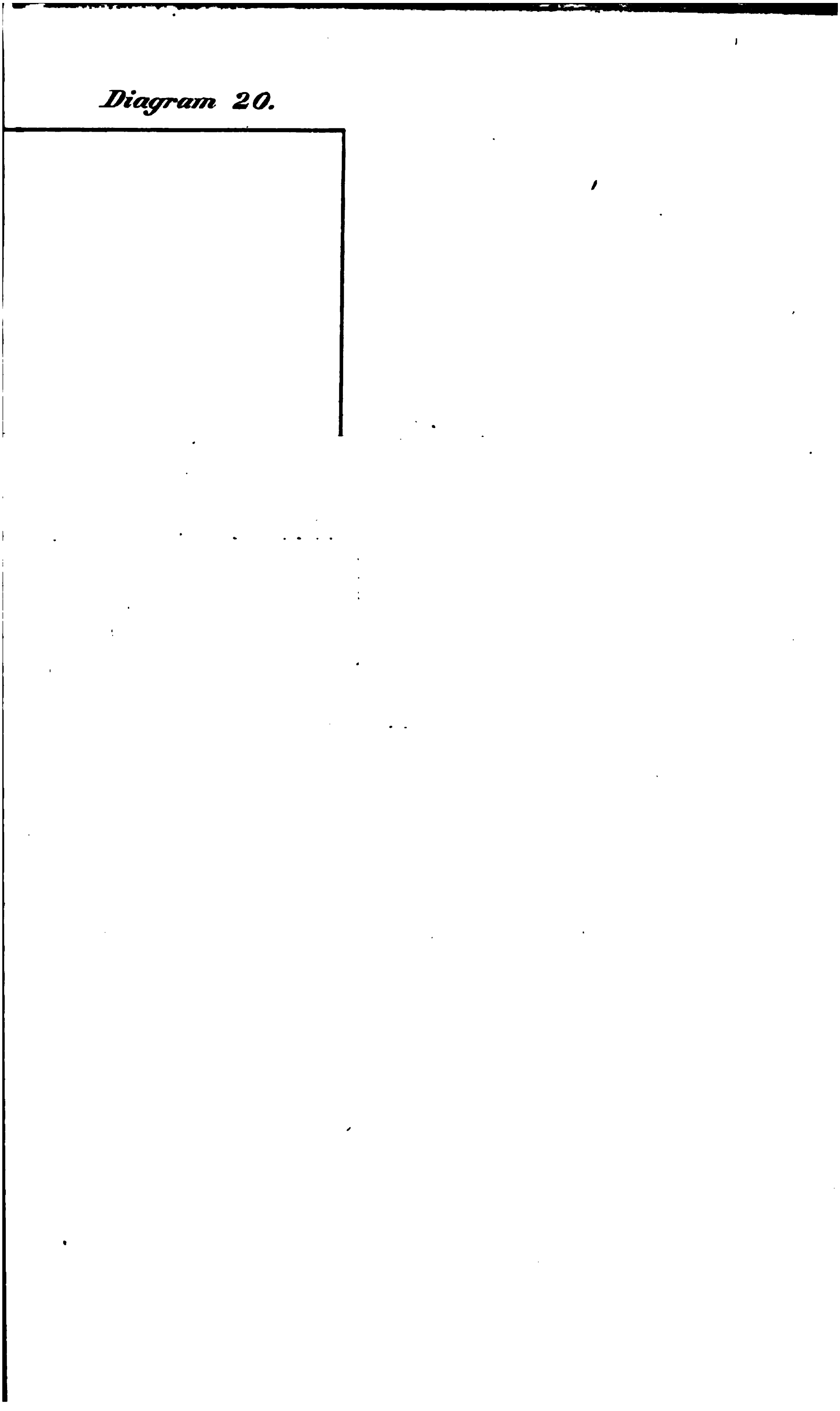

Diagram 21.

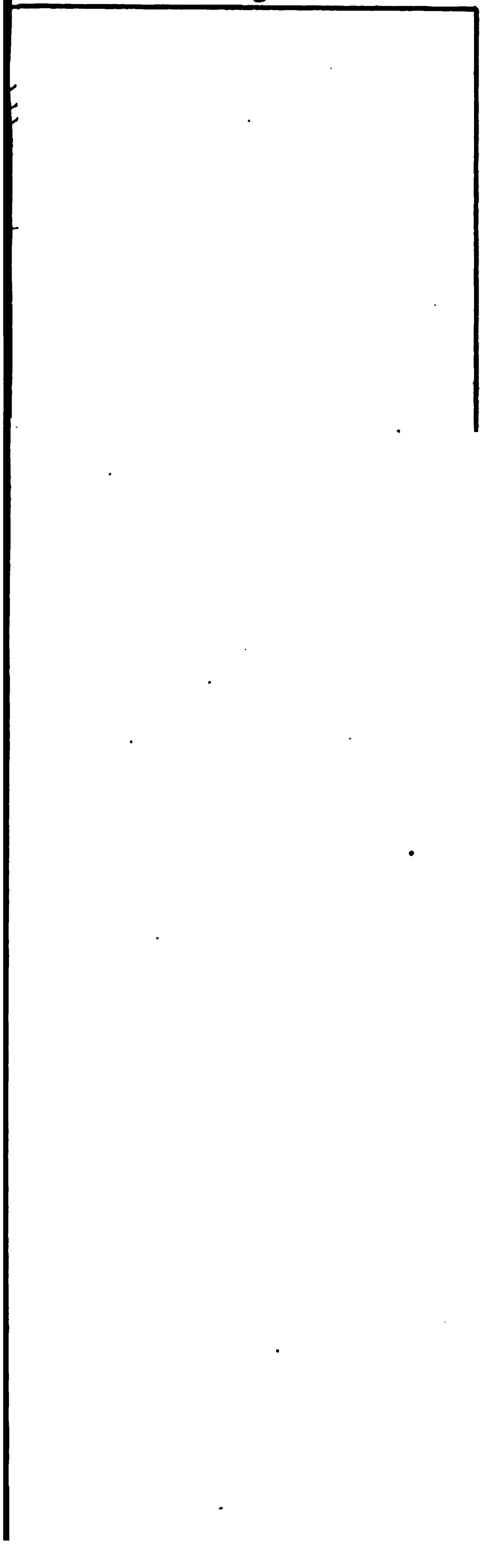

Diagram 22.

Diagram 23.

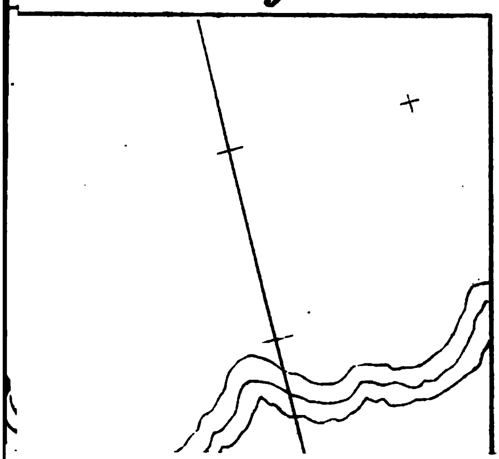

Diagram 24.

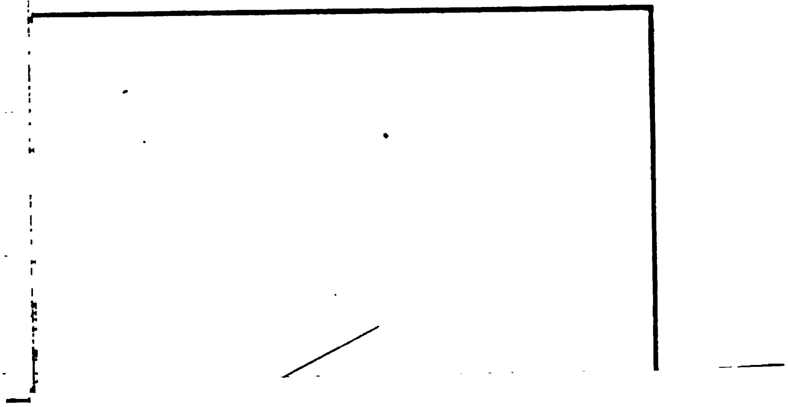

Diagram 25.

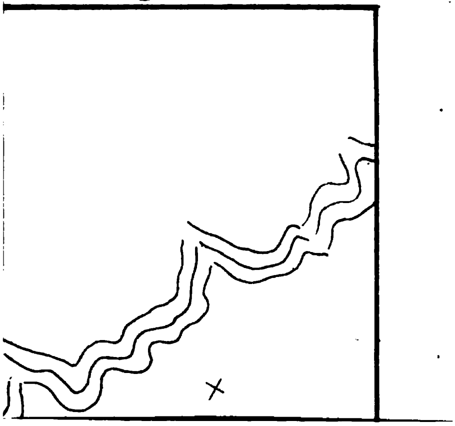

Diagram 26.

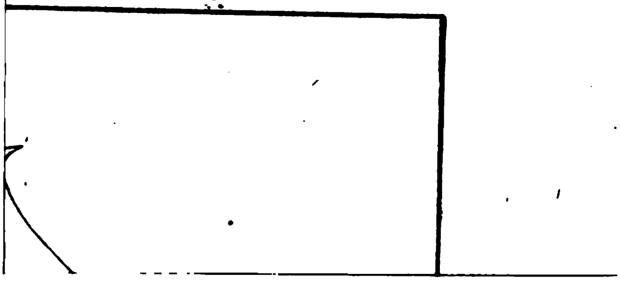

Diagram 27.

pine 4' long and 2"x2" in section,
position of these floats was de-
nd of a measured base.   These
rse show the course of the floats.
respectively above the zero of the
The range between high and low
re located by triangulation and

Diagram 28.

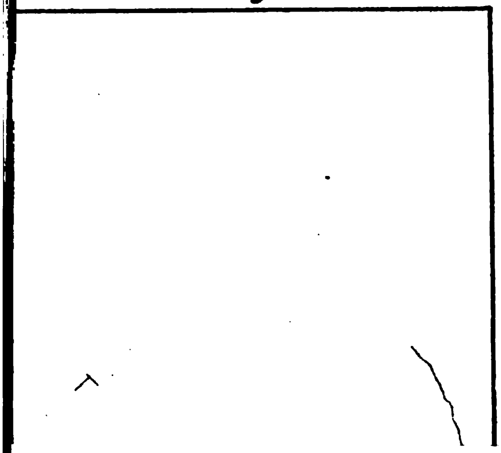

Diagram 29.

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hich is as follows.

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between St. Paul in
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on of the river."

A greater depth than $3\frac{1}{2}$ feet would allow the formation of a bank before the dipper, through which it, in the ascent, could readily obtain the material to fill to its full capacity. Again, as the depth to be removed falls below $3\frac{1}{2}$ feet, the dredge must be moved frequently, adding to the time practically lost.

It then seems permissible to say that under circumstances otherwise similar, if the cost of the removal of rock having a depth of 3.5 feet be taken as 1, then the cost for all depths less than 3.5 feet will be nearly equal to 1, and for depths greater than 3.5 feet about proportionate to the increased volumes moved. This presupposes the rock to be fully broken to the required depth.

The fourth condition, or protection against sea and wind, is beyond comparison, except in any one location, and all that can be said is that from the experience of the seasons of 1875-'76-'77 the most favorable time for such work on Lake Superior is in the months of June, July, and August, during which time it is not safe to allow a smaller amount of lost time through bad weather than about one-sixth, and it may in any one season be as much as one-fourth.

The following summary shows the details of the dredge-work:

Working-time, actual	$576\frac{5}{60}$	hours.
Lost time, bad weather	$100\frac{25}{60}$	hours.
Possible time from June 26 to September 6, inclusive	63	days.
Days and parts of days dredge was working	47	days.
Average time made per day	$12\frac{26}{100}$	hours.
Used in making repairs in otherwise working-time	83	hours.
Used in making repairs in bad weather	46	hours.
Rock removed by dredge	3,000	cubic yards.
Bowlders removed by dredge	200	cubic yards.
Rock, coarsely broken, removed by aid of diver and hoisting-scow	150	cubic yards.
Average depth of rock removed	$2\frac{6}{10}$	feet.
Maximum depth of rock removed	5.0	feet.
Area of excavation	35,000	square feet.
Average amount of rock removed per hour by dredge	$5\frac{55}{100}$	cubic yards.

NOTE.—The cubic yard of rock herein mentioned means prism measurement. The material removed, reduced to scow measurement, becomes 5,964 cubic yards.

COST OF WORK.

The following statements of cost of work cover the items of labor and material expended:

Cost of drilling.

Actually used in drilling:		
Labor	$2,101 16	
Wood, 70 cords, at $3	210 00	
Oil, 30 gallons, at 50 cents	15 00	
		$2,326 16
Sharpening drills:		
Labor	229 81	
Coal, 2 tons, at $8	16 00	
Steel, 123 pounds, at 15 cents	18 45	
		264 26
Erecting and maintaining platform:		
Labor	1,237 40	
Wood, 30 cords, at $3	90 00	
Oil, 10 gallons, at 50 cents	5 00	
		1,332 40
		3,922 82

This was applied to the drilling of 5,387 linear feet of hole:

Cost of drilling per linear foot	$0 73
Cost of drilling per cubic yard of rock	1 17

Cost of blasting.

Labor, specially used in blasting	$895 89
Dynamite No. 1, 1,450 pounds, at 90 cents	1,305 00
Dynamite No. 2, 5,600 pounds, at 45 cents	2,520 00
Exploders, 1,210 each, at 30 cents	363 00
Wood, 10 cords, at $3	30 00
Oil, 3 gallons, at 50 cents	1 50
	5,115 39

This was applied to blasting 576 holes having an average depth of 7.2 feet and covering an area of 32,000 square feet:

Cost of blasting per hole	$8 [illegible]
Cost of blasting per square foot	0 15
Cost of blasting per cubic yard	1 22

Cost of removing the broken rock.

Hire of dredging equipment	$7, 991 18
Labor, removing rock by hand (*a*)	731 [illegible]
Wood, used by item (*a*), 25 cords, at $3	75 [illegible]
Oil, used by item (*a*), 5 gallons, at 50 cents	2 50
	8, 799 6

This was applied to the removal of 3,350 cubic yards of material by dredging and hand removal:

Cost per cubic yard of material removed	$2 6
Material removed by dredge, cost	2 [illegible]
Material removed by hand, cost	5 40

The area covered by the material to be removed was 35,000 square feet; in terms of this area, the cost of dredging was 22.8 cents per square foot. But of this area 19,000 square feet were dredged over a second time; if this be added to the previous area the cost would be 18.2 cents per square foot. The following were the prices paid for labor:

Skilled labor, mechanics, from	25 to 30 cents per hour.
Diver labor, from	30 to 40 cents per hour.
First-class labor, from	22 to 25 cents per hour.
Second-class labor, from	18 to 20 cents per hour.
Third-class labor, from	16 to 18 cents per hour.
Fourth-class labor, from	14 to 16 cents per hour.

The following was the average organization of the labor force during the work.

1 overseer. }
1 machinist. } Skilled labor.
1 blacksmith. }
1 diver.
1 first-class laborer.
3 second-class laborers.
4 third-class laborers.
1 fourth-class laborer.

DISBURSEMENTS UNDER LAST PROJECT.

Classification.	Amount.
For machinery	$4, 515 64
For tools	1, 980 10
For boats	983 77
For supplies	7, 924 25
For storage	25 00
For transportation	635 91
For dredging, hire of equipment	7, 991 18
Labor, office expenses, and contingencies	12, 814 10
Superintendence	6, 070 19
Aggregate	42, 940 13

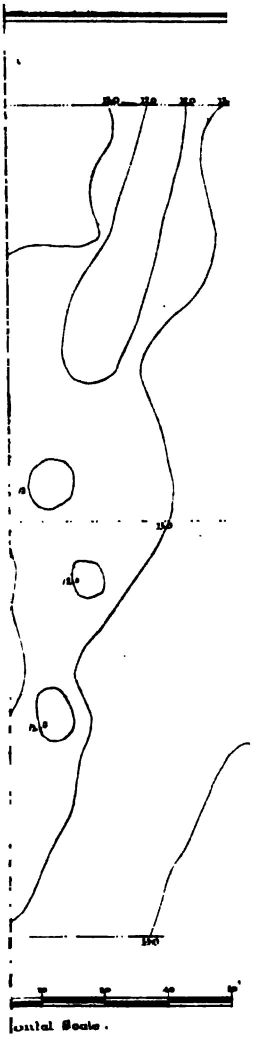
The machinery, tools, boats, and supplies were purchased at favorable prices, and have an estimated present value as follows:

Machinery	$2, 000
Tools	1, 000
Boats	550
Supplies	350
Present value	3, 900

The following statement shows the cost of removing 3,350 cubic yards of material in place (prism measurement), equal to 5,964 cubic yards, scow measurement:

1st. Cost, inclusive of all disbursements: $12.82 per cubic yard, prism measurement, or $7.20 per cubic yard, scow measurement.

2d. Cost, less office expenses: $11.99 per cubic yard, prism measurement, or $6.74 per cubic yard, scow measurement.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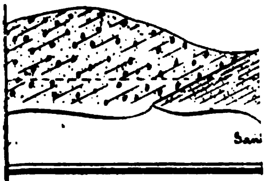
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3d. Cost, less office expenses and present value of property: $10.83 per cubic yard rism measurement, or $6.08 per cubic yard, scow measurement.

The past history of this work shows that it has twice been under contract, without, n either case, effecting improvements of value to the harbor.

In 1867 a contract was made with D. Quinn, at $58 per cubic yard.

In 1869 a second contract was made with G. Townsend, at $40 per cubic yard.

Both contracts failed in results, and were annulled by the government. In these fforts there had been expended, previous to 1874, $41,791.72, an amount nearly equal o the entire expenditure under the last project.

I do not think that the work could have been placed under contract, in 1875, for ess than $30 per cubic yard.

Under the last project the government invested $15,403.77 in an outfit for this speial work, or about 36 per cent. of the entire expenditure, and were then able to do he work for less than one-third of the price paid to last contractor.

This, at least, shows an exception to the oft-made assertion, that "it costs the government more to do work by hired labor than by contract."

In work where the element of uncertainty is involved as to results, the contractor naturally allows wide margin in his supposed estimate of cost. If the plan upon which the work is done proves successful, the government probably pays heavily for this element of uncertainty; while, if the plan proves a failure, the contract becomes annulled, and the government loses by the necessary delay. In either case the government is placed at a disadvantage. Hence, in work involving this element of uncertainty, it would seem to be advantageous for the government to do the work by hired labor rather than by contract.

PERMANENCY OF THE IMPROVEMENT MADE

During the winter months the ice accumulated upon and in the vicinity of the ledge, through which the entrance has been made, in immense masses, reaching from the surface of the ledge to a height of 10 feet above the water surface. The tendency of movement in these ice masses is to move the detritus with which the bottom is covered from place to place, a large part of which will probably be forced into the cut recently made. It may not be a rapid process, but it is probable that a dredge will have to be employed at not very frequent intervals to remove these accumulations.

FURTHER IMPROVEMENTS.

Concerning the further work as set forth in the original project, viz, the construction of breakwaters inclosing the harbor, I am convinced that the opinions given in my reports of 1875 and 1876 are sound, *i. e.*, that such breakwaters would add but little to the value of Eagle Harbor, and in the present condition of lake commerce would be almost useless.

The commerce of Eagle Harbor is nearly dependent on the copper mines in the vicinity. These are yearly growing less productive, and, with the exception of a single mine, are almost reduced to nil. Again, the mines tributary to Eagle Harbor are removed at the farthest about 25 miles from the present terminus of a railroad carrying to Hancock. The cost of hauling copper to Eagle Harbor, a distance of from 3 to 8 miles, and supplies therefrom, many times exceeds the probable freight rates from these mines to Hancock.

If the copper mines again become remunerative, the interests of the railroad will cause its extension to these mines, in which event the commerce of Eagle Harbor is practically gone.

I would, however, urge the necessity of placing 90 linear feet of guiding-cribs on west side and 45 feet on east side of excavated channel, for which the following revised estimate is submitted:

Three cribs with superstructure 45 feet long, 24 feet wide, and about 18¼ feet high:

14,435 cubic feet pine timber in crib, at $24	$3,464 40
22,000 pounds 1¼-inch drift bolt, at 4½ cents	990 00
310 cords stone, at $8	2,480 00
13,000 feet, board measure, 4-inch plank, at $14	182 00
450 pounds 8-inch spike, at 4 cents	18 00
5 cords brush, at $4	20 00
	7,154 40

Range lights were erected by the United States Light-House Department during the season of 1877 on the center line of the recent excavation. I wish to record the intelligent and valuable co-operation of Mr. E. T. Williams and his able superintendent, Mr. F. Dygart, in the work of dredging; also, the services of Mr. J. F. Huston, who has ably and ingeniously discharged the duties of overseer during the entire work.

All of which is most respectfully submitted by

Your obedient servant,

L. Y. SCHERMERHORN,
Assistant Engineer.

Maj. H. M. ROBERT,
Corps of Engineers, U. S. A.

COMMERCIAL STATISTICS.

Name of harbor, Eagle Harbor, Michigan; collection-district, Superior, Michiga nearest light-house, Eagle Harbor, Michigan.

Arrivals and departures of vessels during the year ending December 31, 1877.

	Arrivals.			Departures.		
	No.	Tonnage.	Crews.	No.	Tonnage.	Crew
Steamers	144	103, 310	....	144	103, 310	....
Sailing-vessels	5	1, 610	18	5	1, 610	1
Total	149	104, 920	....	149	104, 920	....

Exports for the year ending December 31, 1877.

Copper	tons..	1, 746¼	Beer	barrels..	311
General merchandise	tons..	100	Old iron	tons..	3
Hides	tons..	22	Bones and rags	tons..	10

Imports for the year ending December 31, 1877.

General merchandise	tons..	479	Whisky	barrels..	46
Coal	tons..	411	Oil	barrels..	150
Iron	tons..	61¼	Lumber	feet, b. m..	162,000
Hardware	tons..	81¼	Lime	barrels..	462
Powder	tons..	25¼	Brick	number..	69,000
Miscellaneous	tons..	57	Stock	head..	243
Oats	bushels..	16, 847	Hogs and sheep	number..	162
Corn	bushels..	6, 633	Machinery	tons..	122
Flour	barrels..	2, 464	Ale and wine	barrels..	152
Hay	tons..	24	Cement	barrels..	575
Feed	tons..	183	Lath and pickets	number..	18,000
Salt	barrels..	105	Shingles	number..	160,000

This information was obtained from Raley & Shapley.

Z 3.

IMPROVEMENT OF MARQUETTE HARBOR, MICHIGAN.

The breakwater at this harbor was built 10 feet longer than originally contemplated, at a cost of $306,255.75, which was $78,873.83 less than the estimated cost. It should be extended, eventually, 400 linear feet farther, which would cost, it is estimated, $68,000.

The only operations during the past fiscal year were some repairs made on the breakwater where damaged by a vessel striking it. An extensive examination was made to ascertain the condition of the breakwater, which requires a large quantity of stone as refilling—about 1,000 cubic cords. Of this quantity, about 400 cords will be put in during the present season, and the rest should be placed in the work during the fiscal year 1879–'80, for which purpose, with such repairs as are always needed at this harbor, the sum of $5,000 is asked. The violence of the sea during storms is very great at this point, and by it the breakwater is often extensively injured. As the riprap and filling continue to settle, more stone will be required from time to time.

Money statement.

July 1, 1877, amount available	$2,490 90	
Amount appropriated by act approved June 18, 1878	2,000 00	
		$4,490 90
July 1, 1878, amount expended during fiscal year		1,532 59
July 1, 1878, amount available		2,958 31
Amount that can be profitably expended on repairs in fiscal year ending June 30, 1880		5,000 00

COMMERCIAL STATISTICS.

Name of harbor, Marquette, Mich.; collection-district, Superior, Mich.; nearest light-house, Marquette, Mich.

Arrivals and departures of vessels during the year ending December 31, 1877.

	Arrivals.			Departures.		
	No.	Tonnage.	Crews.	No.	Tonnage.	Crews.
Steamers	193	175,968	2,904	191	176,003	2,963
Sailing-vessels	329	193,358	2,721	346	201,956	2,851
Total	522	369,326	5,625	537	377,959	5,814

Exports for the year ending December 31, 1877.

Lumber	feet board-measure	8,327,240	Iron ore	tons	602,968
Fish	packages	100	Bar-iron	tons	2
Fish	tons	116	Scrap-iron	tons	591
Sandstone	cubic feet	59,000	Berries	bushels	3,148
Powder	kegs	23,000	Horses	number	6
General merchandise	tons	828	Quartz	tons	1,950
Pig-iron	tons	18,143	Limestone	tons	86

Imports for the year ending December 31, 1877.

General merchandise	tons	8,657	Coal	tons	26,840
Hay	tons	233	Limestone	tons	3,050
Oats	bushels	32,290	Coke	tons	5,169
Corn	bushels	6,188	Slate	tons	70
Potatoes	bushels	686	Brick	number	51,350
Flour	barrels	2,410	Bar-iron	tons	68
Whisky	barrels	101	Nitrate soda	tons	525
Oil	barrels	455	Brimstone	barrels	200
Feed	tons	67	Pitch	barrels	150

This information was obtained from C. Y. Osburn, collector of customs.

Z 4.

IMPROVEMENT OF MENOMONEE HARBOR, MICHIGAN AND WISCONSIN.

Estimated cost of present plan of improvement	$212,000 00
Appropriated to date	143,000 00
Leaving to be appropriated	69,000 00
Amount required for the fiscal year 1879–'80	40,000 00

The operations during the past fiscal year comprised building and placing in position 5 cribs, 3 on the north and 2 on the south pier, in extension of the same, without superstructure. The work was done by Messrs. Truman & Schrader, of Manitowoc, Wis., under contract. The north pier cribs were of the "Chicago" model devised by Maj. D. C. Houston, Corps of Engineers. They have maintained their position better than those of the old style, and are more easily located.

A resurvey of the channel was made, showing a 14-foot channel to the heads of the piers extending up the river for 1,000 yards, and 13 feet of water across the bar. An examination of the piers was made last month.

The location of the channel across the bar being directly in the line of the pier extension it became necessary after the north pier cribs were placed to dredge a new channel over the bar. This was done by the Menomonee Dredge Company at 10 cents per cubic yard, 3,723.8 cubic yards being removed.

The operations contemplated during the present season are the construction and placing of 3 new cribs in extension of the piers; superstructure over the 5 cribs placed last year, and such dredging, refilling, and repairs to the piers as may be necessary. The amount asked for the fiscal year 1879–'80 will be applied to further pier extension according to the approved plan.

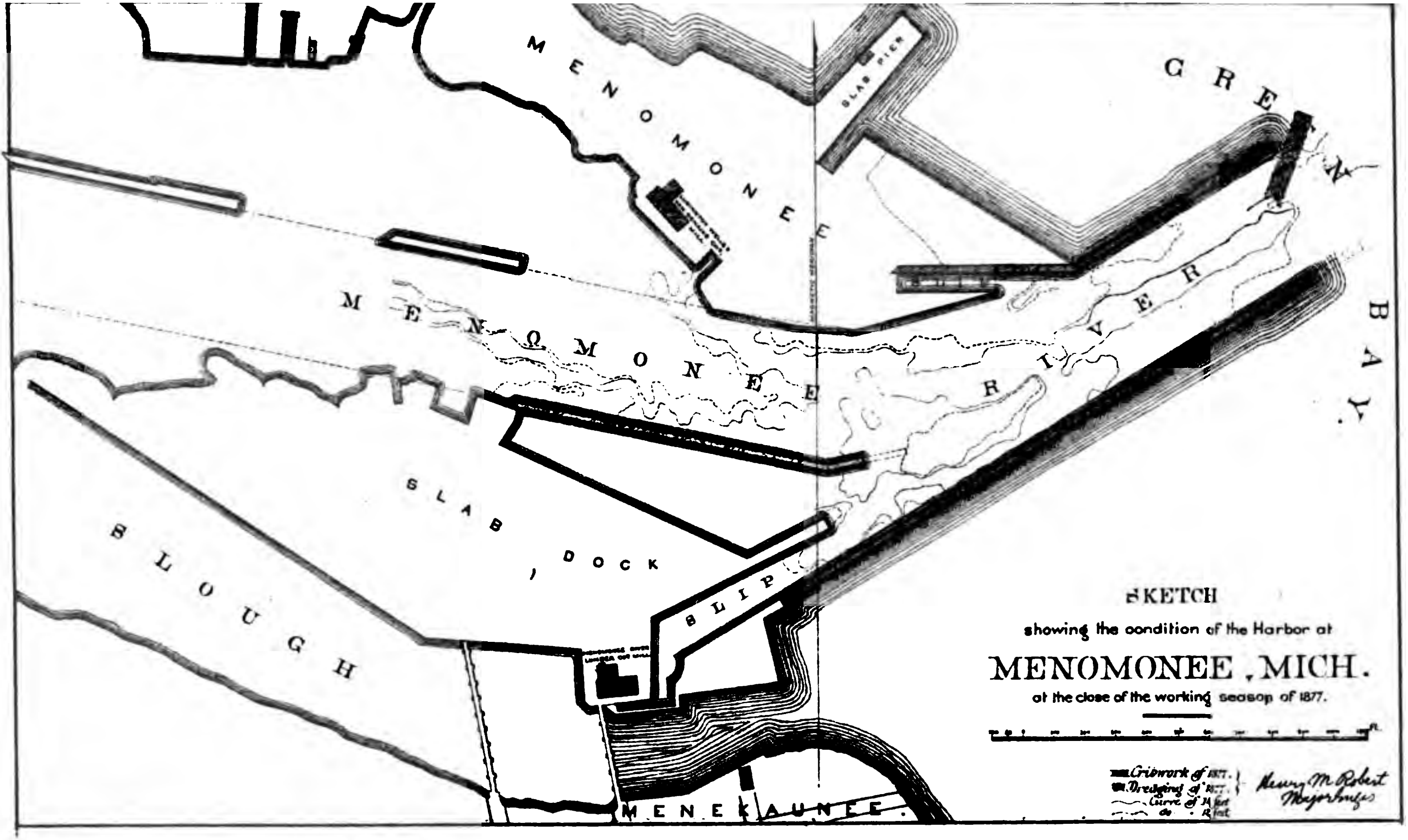
Money statement.

July 1, 1877, amount available	$9,531 23	
Amount appropriated by act appropriated June 18, 1878	10,000 00	
		$19,531 23
July 1, 1878, amount expended during fiscal year		9,432 16
July 1, 1878, amount available		10,099 07
Amount (estimated) required for completion of existing project		69,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1880		40,000 00

List of materials used and work done at Menomonee Harbor, Michigan and Wisconsin, during the season of 1877.

Materials for 5 cribs, 50′ x 20′ x 13½′, and 600 linear feet of plank walk, 3′ x 3″.	Price.	Quantity.	Amount.
Pine timber framed, 12″ x 18″ ... linear feet	$0 20	500	$100 00
Pine timber framed, 12″ x 12″ ... do	22	16,519	3,634 18
Oak timber, framed ... feet board-measure	15 00	4,248	63 72
Piles ... linear feet	06	1,247	74 82
Piles driven ... number	2 50	36	90 00
Bolts, drift, 1⅛ square ... pounds	03	23,497.2	704 92
Bolts, screw ... do	04	396	15 84
Chain ... do	04¾	5,875	279 06
Stone ... cords	4 60	511.6	2,353 36
Pine plank ... feet board-measure	7 50	8,852	66 39
Laying plank ... do	1 00	8,852	8 85
Spikes, wrought ... pounds	03½	385	13 47
Total			7,404 61

Average cost of cribs, Chicago model, each	$1,494 38
Average cost of cribs, Chicago model, per linear foot	29 89
Average cost of cribs, old model, each	1,416 50
Average cost of cribs, old model, per linear foot	28 33



SKETCH

showing the condition of the Harbor at

MENOMONEE, MICH.

at the close of the working season of 1877.

COMMERCIAL STATISTICS.

Name of harbor, Menomonee, Mich. and Wis.; collection-district, Superior, Mich.; nearest light-house, Menomonee, Mich.

Arrivals and departures of vessels during the year ending December 31, 1877.

	Arrivals.			Departures.		
	Number.	Tonnage.	Crews.	Number.	Tonnage.	Crews.
Steamers	130	45, 100	1, 789	129	44, 600	1, 776
Sailing vessels	521	141, 500	2, 850	520	141, 250	2, 841
Total	651	186, 600	4, 639	649	185, 850	4, 617

Exports for the year ending December 31, 1877.

Lumber	feet b. m.	150, 000, 000	Fish	packages	10, 000
Pickets	number	2, 000, 000	Ice	tons	1, 200
Posts	number	450, 000	Bark	cords	5, 000
Shingles	number	35, 000, 000	Ties	number	100, 000
Lath	number	3, 500, 000	Wood	cords	50, 000
Pig-iron	tons	3, 650	Machinery	value	$50, 000

Imports for the year ending December 31, 1877.

Hay	tons	800	Stone	cords	650
General merchandise	tons	1, 250	Beef	barrels	2, 500
Flour	barrels	7, 500	Grain	bushels	125, 000
Salt	barrels	750	Feed	tons	750
Lime	barrels	1, 500	Potatoes	bushels	600
Pork	barrels	4, 000	Brick	number	700, 000
Wood	cords	6, 000			

The above information was obtained from James A. Crozer, deputy collector of customs.

Z 5.

IMPROVEMENT OF GREEN BAY HARBOR, WISCONSIN.

Estimated cost of present plan (1872 and 1874) with a small annual appropriation for preserving the harbor	$75, 000 00
Appropriated since	53, 000 00
Leaving to be appropriated	22, 000 00
Amount required for fiscal year 1879–'80	12, 000 00

The importance of this work is sufficiently indicated by its position at the mouth of Fox River, it really forming a part of the improvement of the Fox and Wisconsin Rivers.

The operations at this harbor during the past fiscal year consisted of dredging on the line of the previous work in the channel leading in from Green Bay, which was done under contract with the Green Bay Dredge and Driver Company, reported in the last annual report. The work was commenced August 2 and finished October 11, during which time 39,282½ cubic yards of material were removed, at a cost of 12 cents per cubic yard.

Preliminary to the above work a double line of soundings was taken 10,000 feet long, and a survey of the channel was made in February from the ice as far as possible, and completed in June, to ascertain the exact condition of the bottom and the changes which have occurred in its conformation during the past four years; also, to determine the proper location of future dredging. Three parties were run and 3,800 soundings taken, of which 3,000 were cut through ice. The results are given in the appended reports of the assistants who made the examinations.

During the present season dredging, as before, will be done to obtain a 14-foot channel at ordinary low-water. The same work will be continued, with such repairs to the piers at Grassy Island as may become necessary, during the fiscal year 1879–'80.

Money statement.

July 1, 1877, amount available	$6, 144 43	
Amount appropriated by act approved June 18, 1878	5, 000 00	
		$11, 144 4
July 1, 1878, amount expended during fiscal year		6, 085
July 1, 1878, amount available		5, 058
Amount (estimated) required for completion of existing project		22, 000
Amount that can be profitably expended in fiscal year ending June 30, 1880.		12, 000

REPORT OF MR. L. Y. SCHERMERHORN, ASSISTANT ENGINEER.

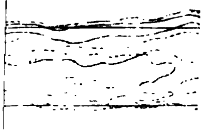
MARCH 13, 1878.

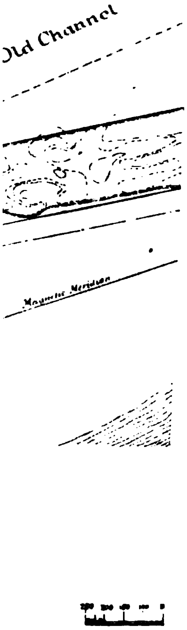
SIR: I have the honor to submit the following report and plat of soundings as the results of the recent survey made at Green Bay. Soundings were taken from the lower end of the cut (near the mouth of Fox River,) northward, to a point about 900 feet south of the revetment piers at Grassy Island; they were again resumed at a point 1,000 feet north of the revetment piers, and continued from this northward for a distance of 1,900 feet, or to beyond the natural contour of 14 feet. The soundings were omitted from the part of the cut above mentioned (for a distance of about 2,600 feet) on account of the absence of ice, or its thinness being such as to prevent their being taken. When the character of the ice made it possible, soundings in cross-section were carried far enough to take in all dredging hitherto done, both in the old and new cut. The soundings on accompanying plat are reduced to low-water of 1867, or a plane 1 foot below waleing strip, at south end of east revetment pier, Grassy Island.

RESULTS OF SURVEY.

An accurate survey of the channel * * * in February and March, 1874, showed an extensive bar had formed across the channel at a point about 1,600 feet southward of the south end of the pier revetment. * * * The appropriation of $10,000 June, 1874, was applied in removing the bar above mentioned, &c. (Report of Chief of Engineers, 1876, Part II, page 343). This bar had its head at about station 37 of soundings between angle and Grassy Island, of transmitted plat. Plat 15 further shows the limits of the dredging above referred to. The transmitted plat clearly shows the extent of this dredging of 1874, and likewise establishes the fact that no tendency has existed toward the reformation of the bar. The transmitted plat of soundings of 1878 further shows the dredging of 1875 in connection with the previous dredging of 1874, *i. e.*, a cut 50 feet in width, extending from the south end of the dredging of 1874 to about the old angle. This cut of 1875 does not seem so well defined as that previously mentioned of 1874. The remainder of the work of 1874, *i. e.*, "at the angle formed by the two reaches" (see Report of Chief of Engineers previously alluded to), seems to be shown by the soundings of 1878 to have been imperfectly done, not having been carried to the limiting lines or to the depth of 14 feet below low-water plane previously mentioned. This conclusion is reached in opposition to the probability of the dredging having at the time been properly done and since vitiated by bar deposits, by an examination of the soundings of 1878, which seem to show an irregularity of bottom over the area of 1874, dredging only reconcilable with such an inference, at points the depth passing from 7.5 feet to 14.8 feet, rising again to 7.5 feet, and falling to 14 feet in consecutive soundings in the same cross-section. These marked irregularities in a sandy bottom, while leading to the above conclusion, at the same time permit the inference that the cut has been free from the disturbing action of currents, and leading to the conclusion that the cut when once made to the proposed depth will remain in a stable condition. This inference as to the permanency of bottom is strengthened by the permanency of the dredging done north of the angle in 1874 and 1875, and previously alluded to.

The urgent need of giving at the earliest possible date a passage through the proposed channel seems to have been recognized from the first, and under the limited




Old Channel
Magnetic Meridian

ad partial appropriations such a yearly application of appropriations has been made would meet the yearly increasing demands of commerce and at the same time work ward the accomplishment of the original project, *i. e.*, to connect the mouth of Fox iver with the deep water of the bay by a channel 200 feet wide and 14 feet deep at w-water.

The following estimates of quantities are submitted. The quantities are for an estiated excavation 1 foot below bottom, and 20 per cent. has been added to cover difrence in volume between dipper and place measurement.

1st. For completion of present project, channel 200 feet wide, 14 feet deep, at low ater.

	Cubic yards.
rom mouth of river to new angle	63,700
rom new angle to station 49 (end of soundings)	28,000
rom station 49 to point 1,000 feet north of pier revetment (soundings recommenced)	30,000
rom point 1,000 feet north of pier revetment to deep water of bay	20,500
	142,200

2d. Project same as foregoing, except a present reduction of channel south of angle d between stations 43 and 69 to a width of 170 feet, measured from east side of annel.

	Cubic yards.
rom mouth of river to new angle	52,000
rom the remaining quantities, as in foregoing	78,500
	130,500

3d. Channel 170 feet wide throughout; channel-width measured from east side of cut r that part south of angle, at angle to be continued in prolongation until the west de of channel is reached, then lying along west side until deep water is reached.

	Cubic yards.
rom mouth of river to angle	48,000
rom angle north to station 49	15,000
rom station 49 to point 1,000 feet north of revetment	15,600
rom thence to deep water of bay	10,000
	88,600

4th. Channel 100 feet wide, *i. e.*, 50 feet on each side of present center line.

	Cubic yards.
om mouth of river to new angle	22,000
om angle to station 49	8,000
om station 49 to point 1,000 feet north of pile revetment	9,800
om thence to deep water of bay	7,000
	46,800

NOTE.—In each case the quantities for the section not sounded over, viz, "from stan 49 to point 1,000 feet north of pile revetment," has been estimated by averaging e quantities in the sounded sections, on both ends of the unsounded section, and plying the average quantities thus found, pro rata, to the unsounded section. This tter plan would give a channel of fair width to the full depth by a single season's edging. Thirthy-nine thousand two hundred and eighty cubic yards were dredged 1877, leaving the full width to be obtained by the application of succeeding approiations. It would have the further advantage of afterward permitting the readjustnt of the limiting lines of the channel by moving the angle northward, and thereby re nearly approximating to a straight line between the mouth of the river and assy Island Cut, and this with a comparatively small increase in the dredging. The esent angle of deflection is 11°. Vessels drawing more than 12 feet of water would unable to pass (except by fortuitous and devious channel) over the present chanl. I understand that last season the grounding of vessels and partial transferment cargoes was not unfrequent. To facilitate dredging on definite lines and assist vess and tugs in keeping the channel, guiding piles should be driven adjacent to the t.

Very respectfully, your obedient servant,

L. Y. SCHERMERHORN,
Assistant Engineer.

Maj. H. M. ROBERT,
Corps of Engineers, U. S. A.

REPORT OF MR. CHARLES CROSMAN, INSPECTOR.

MILWAUKEE, WIS., *June* 21, 1878.

SIR: Referring to the report of Assistant L. Y. Schermerhorn, dated March 13, 1878, relative to the survey of Green Bay Harbor, I have the honor to report that I have completed the survey of that portion of the cut that could not be made in February last on account of thin ice, viz, through Grassy Island 700 feet, south of the island 900 feet, and north of the island 1,000 feet, making a total distance of 2,600 feet. The soundings were taken 20 feet apart on cross-sections of 50 feet, a total of about 750 soundings.

Very respectfully, your obedient servant,

CHAS. CROSMAN, *Inspector.*

Maj. HENRY M. ROBERT,
Corps of Engineers, U. S. A.

COMMERCIAL STATISTICS.

Name of harbor, Green Bay, Wisconsin; collection-district, Milwaukee, Wis.; nearest light-house, Grassy Island, Wisconsin.

Arrivals and departures of vessels during the year ending December 31, 1877.

	Arrivals.			Departures.		
	No.	Tonnage.	Crews.	No.	Tonnage.	Crews.
Steamers	145	67,735	2,371	151	68,526	[illegible]
Sailing-vessels	110	27,762	753	108	27,573	[illegible]
Total	255	95,497	3,124	259	96,099	[illegible]

Exports for the year ending December 31, 1877.

Lumber, feet, board measure	70,000,000	Flour ... barrels	[illegible]
Shingles ... number	15,709,421	Salt ... barrels	[illegible]
General merchandise ... tons	4,827	Cattle ... head	[illegible]
General merchandise ... pkgs	279,411	Oil, carbon ... barrels	[illegible]
Pig-iron ... tons	9,472	Staves ... number	[illegible]
Fish ... packages	2,247	Empty barrels ... number	[illegible]
Wheat ... bushels	1,032,830	Stone ... tons	[illegible]

Imports for the year ending December 31, 1877.

General merchandise ... tons	1,720	Coal ... tons	[illegible]
General merchandise ... pkgs	67,940	Liquor ... packages	[illegible]
Oil, carbon ... barrels	10,080	Railroad iron ... tons	[illegible]
Pork ... barrels	1,647	Stone ... tons	[illegible]
Fish ... barrels	4,971	Apples ... barrels	[illegible]
Cement ... barrels	3,000	Salt ... barrels	[illegible]
Iron ore ... tons	19,930		

The above information was obtained from Jule R. Morris, deputy collector.

Z 6.

HARBOR OF REFUGE AT ENTRANCE TO STURGEON BAY CANAL, WISCONSIN.

Original estimate	$180,000 00
Appropriated since	80,000 00
Leaving to be appropriated	100,000 00
Amount required for the fiscal year 1879–'80	60,000 00

During the past fiscal year some slight repairs were made on the piers, ut the available funds being so small but little could be done; 52.6 cords f stone were placed in the outer ends of the piers, and one pile was riven and capped.

October 30, a set of soundings was taken in the harbor and for 200 eet beyond the ends of the piers. Between the piers at their outer ends he greatest depth found was 13½ feet, the least depth 12.4 feet.

The operations proposed for the present season comprise the extension f the piers by placing 14 new cribs in position by contract, and some repairs to the old piers.

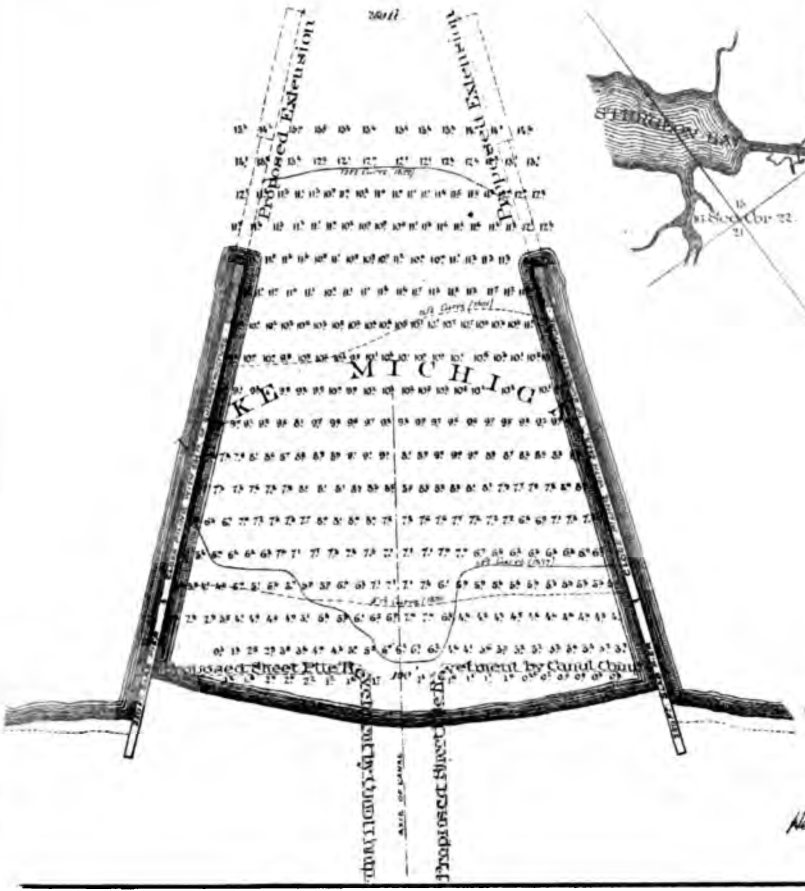
During the fiscal year 1879–'80 the amount available will be applied to further pier-extension and dredging in the harbor.

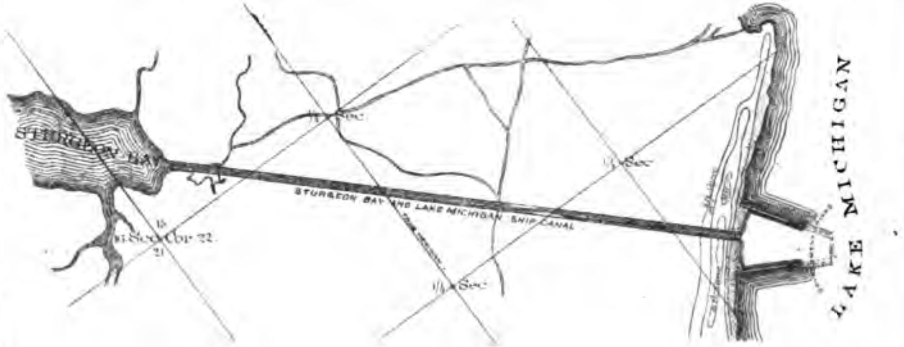
During the past year the canal company has vigorously prosecuted the work, a short, narrow, shallow cut having been made so as to unite the two inner ends of the canal. From present appearances I think the canal will be open to commerce by the close of the season of 1879, as I stated in my special report on this harbor last January. In addition to the difficulties mentioned therein connected with the completion of the canal, arising from the improper valuation of the land donated to the State for constructing the canal, there is also cause for doubt as to whether the canal company will ever keep the canal open after its completion. The act of Congress making the grant of land "to aid in the construction of a breakwater and harbor and ship-canal at the head of Sturgeon Bay" does not require the sides of the canal to be revetted, and while it requires a depth of 13 feet of water, it does not specify the datum from which this depth is to be measured. The canal is now being excavated to a depth of 11 feet below the level of the lake in June, 1847, as reported by Assistant Engineer L. Y. Schermerhorn, which will probably give a depth of 13 feet during the middle of next summer, as it did the last two years. But the lake varies more than 3 feet in its level, and the canal as now excavated would not have had a depth of 13 feet from the fall of 1863 to the spring of 1870, or from the fall of 1871 to the spring of 1876. If the water was too low when the canal was completed, the company doubtless would not ask for its acceptance until there was a depth of 13 feet. The canal company, in taking a datum 2 feet above the lake level in June, 1847, has practically reduced the depth of the canal to an average of about 12 feet.

The other difficulty mentioned above, the lack of protection to the sides of the canal, will probably result in a gradual reduction of its depth. The two combined may render the annual expense of keeping the canal open so great as to lead the company to abandon it.

In spite of these defects in the original legislation and in the valuation of the lands, of which the company have taken advantage, and which cast a doubt over the future of the canal, still it seems to me that the government should complete the protection piers at the entrance to the canal as quickly as possible. It is not now a question as to the policy of undertaking the work from the beginning, but rather whether the government should not now complete the piers after having appropriated one-half their entire cost, besides giving 200,000 acres of land to help to construct the canal.

The officers of the canal requested last summer that the government dock their lake-front between the harbor-piers, and also the canal itself for a few hundred feet. After an examination of the question, including a personal inspection of the premises with the officers of the company, I addressed to the president of the company a letter (a copy of which is annexed hereto) stating, as my opinion, that the canal company were


Proposed Extension
Proposed Extension
LAKE MICHIGAN
Proposed Sheet Pile Revetment by Canal Company
Proposed Sheet Pile Revetment by Canal Company
Axis of Canal



SKETCH

showing the condition of the
Harbor of Refuge at the entrance of

STURGEON BAY CANAL, WIS.

June 30th 1878.

Scale:

50 25 0 50 100 150 200 250 300 350 400 450 500 550 600 650 700 750 ft.

▬ : *Piers refilled in 1877.*
Soundings reduced to low water of 1847,
which is about 2 feet lower, than the present stage.

Henry M Robert
Major Engrs

place of refuge. This change incidentally helps the canal company and saves them the expense of breakwaters, but it must not be overlooked that this was not the object of the appropriations. It was done because it was to the interest of the United States and to commerce, and not to help the canal company. The United States, if it sees fit, may abandon the work, and in that case the canal company would have to build a breakwater or forfeit all the lands remaining unsold at the expiration of the time allowed for the completion of the "*breakwater*, harbor, and canal." (Sec. 4 of act.

In conclusion, I would say that I cannot see that the government is in any way under any obligations to do anything for the canal company. It has already done all it has agreed to do, by transferring to the State of Wisconsin the 200,000 acres of land donated to aid the enterprise. The piers being built by the government are a part of the canal project, and were not primarily intended to save the canal company the expense of building a breakwater. The government has nothing more to do with building docks along your harbor-front and protecting the sides of your canal at the mouth than it has to do with building docks along the shore in the village of Ahnapee. In other words, you have to look out for your own property just as any other company would have to do, and not look to the government to protect it. If the United States were to do what you ask, and build docks along your entire harbor-front between the government piers, and also revet your canal for, say, 100 feet inside its mouth, why should it not also revet the canal 1,000 feet, or, in fact, the entire distance? I cannot see any difference in the principle, and I do not understand that the appropriations for "improving a harbor of refuge at the entrance to the Sturgeon Bay Canal" are available for that purpose.

Trusting that you will see that it does not lie within my power to grant your request, I remain, respectfully, your obedient servant,

HENRY M. ROBERT,
Major of Engineers.

Mr. JESSE SPAULDING,
President Sturgeon Bay and L. M. S. C. and H. Company.

SPECIAL REPORT ON IMPROVEMENTS MADE ON THE STURGEON BAY AND LAKE MICHIGAN SHIP-CANAL AND HARBOR.

UNITED STATES ENGINEER OFFICE,
Milwaukee, Wis., January 25, 1878.

GENERAL: In compliance with instructions contained in your letter of the 19th instant, referring to me the resolution of the House of Representatives calling for information "relative to the improvements made on the Sturgeon Bay and Lake Michigan Ship-canal and Harbor up to the close of season's operation of 1877," I have the honor to submit the following report:

Learning last summer that the Sturgeon Bay and Lake Michigan Ship-canal and Harbor Company were vigorously prosecuting the work, I visited the scene of operations last September, in order to ascertain, among other things, what were the probabilities of the canal's ever being completed. While the canal is in no way under government control, yet upon its completion depends the advisability of continuing work on the government piers near the mouth of the canal.

As the result of this examination, the work being about half completed, my own opinion was favorable to the probability of the early completion of the canal. The most serious cause of doubt was the following fact reported by the commissioners appointed by the State of Wisconsin in 1876 to examine into this very question:

> Your commission believe that the first and second class lands were appraised too low, and the third and fourth class too high. Inasmuch as the company selected almost entirely from first-class lands, we believe they have obtained a patent for more than one-fourth in value of the entire grant. We arrive at this conclusion from the testimony taken, which proves that a large amount of the land classified as third and fourth class is worthless, containing no pine, and being unfit for agricultural purposes, and that a considerable portion of the first and second class land is worth more than the average price fixed by the appraisers. (See annual report of the secretary of state of Wisconsin for 1876, page 53.)

On this account I was anxious to see what the State would do this ear about the land-grant. On November 26, the State inspector, Mr. ohn Nader (who was one of the commissioners above referred to), rote me as to the results of his survey and inspection of the canal just ade, as follows:

> I made a very thorough personal survey and very careful estimates, and find that ere is done to exceed one-half the entire work the amount of 58,100 cubic yards. obtain this by computing the amount yet to be done, making due allowance for con- ngencies, and deducting 10 per cent. of what was done since last inspection (on count of its unfinished state), and deducting from inspector's estimate. I consider is a reasonable margin for the safety of the State, and sufficient warrant for con- nuance of the work. The progress has been greater than I or the company's officers pposed it to be. The lumbering interests of some of the stockholders would now be n incentive to complete the work. The governor is absent; I will inform you further hen he returns.

And again, on the 11th of January, he wrote as follows:

> The governor has issued certificate for the second quarter in quantity of the "grant," n the decision and by advice of the supreme court and the attorney-general. I think, owever, that the work will go on, as the same is sufficiently advanced to warrant its ntinuance.

I herewith transmit a copy of the full report of the State inspector to he governor, and also a communication from Mr. William T. Casgrain, he engineer of the canal company, showing what has been done since he date of the State inspection, and a map.

In conclusion, I would say that I think it exceedingly probable that he canal will be open for navigation by the close of the season of 1879. he outside harbor, being built by the government, should be completed bout the same time.

No appropriation has been made by Congress for the harbor of refuge ince 1874, the appropriation then made being for the year ending June 0, 1875. My predecessor, Major Houston, stated that $60,000 would be equired for the next fiscal year, provided the work on the canal, which ad been suspended, be continued. For the next year (1876-'77) I recom- ended $40,000, provided the work was resumed, and since then have nly asked for $5,000 for repairs. The original estimate for this work as $180,000, of which $50,000 has already been appropriated. Of the emaining $130,000 I would now recommend that $60,000 be appropriated, o be made available as soon as possible.

Very respectfully, your obedient servant,

HENRY M. ROBERT,
Major of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

ETTER OF MR. WILLIAM T. CASGRAIN, ENGINEER STURGEON BAY CANAL COMPANY.

OFFICE OF THE STURGEON BAY AND LAKE MICHIGAN
SHIP CANAL AND HARBOR COMPANY,
Milwaukee, January 24, 1878.

SIR: I have the honor to submit herewith for your information the report of Mr. John ader, civil engineer, inspector to his excellency Harrison Ludington, governor of Wis- onsin, relative to the completion of the second quarter of the work on the canal.

More than one-half of the work had been done on November 14, 1877, at which time he inspection was made, and the condition of the work is fully described by Mr. Nader.

Since this report was made there has been removed 9,500 cubic yards, and the distance between the waters is 1,450 feet.

The contract for the entire work has been awarded to O. B. Green, esq., of Chicago, who has agreed to complete the canal on or before the 1st of December, 1879. Mr. Green has now on the work all the necessary machinery to complete the canal according to the terms of the contract.

I would respectfully call your attention to the fact that, owing to the small amount of appropriations made from time to time by Congress for the construction of the piers to protect the lake entrance to the canal, it will take at least five years to complete these works, and the canal is likely to be available before the United States works are finished.

Preparations should also be made for the construction of the necessary light-houses and beacons in Sturgeon Bay and at the lake entrance to the canal.

Very respectfully,

Wm. T. Casgrain,
Engineer Sturgeon Bay Canal Company

Maj. H. M. Robert,
Corps of Engineers, U. S. A.

REPORT OF MR. JOHN NADER, INSPECTOR.

Madison, Wis., *November* 23, 1877.

Sir: I have the honor to inform you that in accordance with your instructions of November 9, 1877, I have made an examination and survey of the work of the Sturgeon Bay and Lake Michigan Canal, and beg leave to submit the following report:

Taking as a basis the quantities estimated by Mr. Leonard Martin, inspector for the first quarter in September, 1873, I find that the work done since that time is considerable in excess of one-quarter, and that the Sturgeon Bay and Lake Michigan Ship Canal and Harbor Company is entitled to the benefits of a second quarter of work completed.

My estimates are based upon the same dimensions as those of the first inspector, viz. 100 feet width at the water-line, with slopes of 2 base to 1 perpendicular, and 13 feet depth of water, the plane of reference being taken at the level of the lowest water of 1847, the same being the lowest on record by $\frac{7}{10}$ feet.

On arriving at the work and observing the progress made, I concluded to ascertain the amount remaining undone, in order to determine the exact progress of the work.

The contract for the entire work was let to Mr. O. B. Green, of Chicago, at the commencement of the season, and is conducted under the supervision of the efficient chief engineer, Capt. William T. Casgrain. The facilities rendered by these gentlemen enabled me to make a complete survey of the bay and canal.

Three lines of soundings were taken in the cut of the canal, and in Sturgeon Bay as far as deep water, also levels on cross-sections of the canal at intervals of 50 feet. Soundings and levels were reduced to the plane of the lowest water of 1847, and compared exactly with the engineer's recorded notes.

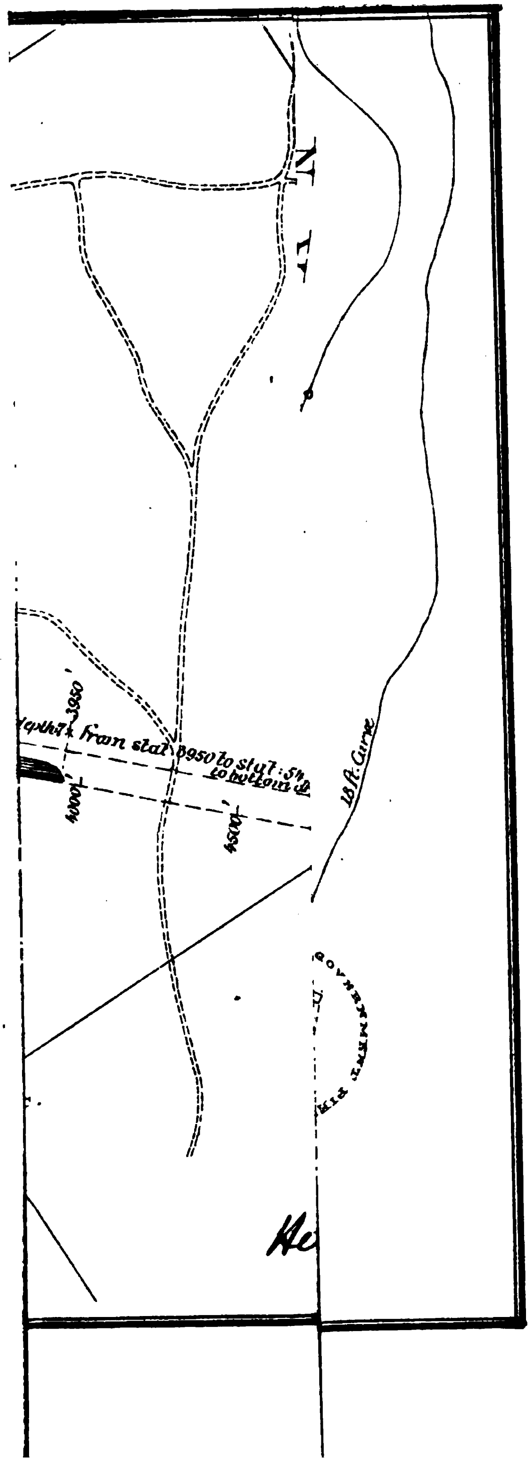
A line of check-levels along the reference-marks upon which the work is based, exhibited only a difference within the limits of probable and admissible errors.

I estimate the following amount of work remaining undone November 14, 1877:

	Cubic yards.
From Sturgeon Bay to high-water line, Lake Michigan	297,000
Excavation from bermes and drains	37,000
Excavation in mouth of canal, Lake Michigan	15,000
Excavation in Sturgeon Bay to deep water	54,000
Excavation for incomplete work to date	31,700
Total remaining undone	434,700

Inspector's estimate for 1873 was—

For clearing and grubbing 600 feet wide	38,400
For excavation in bay and canal	960,000
Total estimate of entire work	998,400

3950
epth 7' from stat 3950 to sta 7:54
to bottom
4000
4500
18 ft. Curve

The clearing and grubbing was reduced from 600 feet to 400 feet wide, hich made a proportional difference in quantities, as follows:

learing and grubbing	25,600
xcavation	960,000
Revised total estimate of entire work	985,600
otal done September 4, 1873 (from inspector's report)	255,000
Remaining undone September, 1873	730,600
emaining undone November 14, 1877	434,700
eaving a difference of	295,900
rom which deduct clearing and grubbing	10,600
xcavation done since September, 1873	285,300
otal of all work since September, 1873	295,900
stimate of work done September, 1873	255,000
Total of work done to November 14, 1877	550,900
ne-half of revised total estimate	492,800
eaving an excess over two-fourths	58,100
emaining practically undone November 14, 1877	434,700

The first estimates were very properly made a little in excess to meet contingencies, as e nature of the material, although pretty thoroughly explored, might not have been und as stable as it proved to be. This excess of estimate has been nearly eliminated y the method adopted by me, that of measuring the quantities actually remaining ndone, but will leave a corresponding discrepancy between my results and the engi-er's measurements of perhaps 5,000 cubic yards, the difference being on the safe side.

The condition of the work is as follows:

From a point one mile out in Sturgeon Bay to the canal there is an average depth of 10 et; from the head of the bay to station 3,100 feet southeast in canal, the cut is full width d average depth of water over 11 feet; thence to station 3,700 feet, the cut is two-thirds idth and average depth of over 7 feet; thence to station 5,600 feet, a distance of 1,900 et, there remains to be cut an average of 23 feet from the surface to obtain 13 feet of water; ence to station 6,000 feet, the cut is two-thirds width and average depth of 5 feet of ater; thence to station 6,500 feet, the cut is full width and average depth of 7 feet water; thence to station 7,300 feet, at high-water line of Lake Michigan, the cut is o-thirds width and average depth of 5 feet water. The above depths of water rep-sent the depth below the lowest water of 1847.

The work of the season was not begun until July. Since that time it was pushed rward with energy and determination. Four excellent Osgood dredges and three eam derricks were almost in constant operation to their utmost capacity.

The slopes and banks are in an unfinished condition, the principal object being to move as much as possible of the heavy excavation during the season. In advance the dredges, the surface excavation was removed with wheelbarrows, road-scrapers, d portable railroad.

The material removed was placed in spoil-banks not nearer than 20 feet to the top pe-stakes, so as to prevent a crowding of the banks.

From the present advanced condition of the work, it is safe to say that if the same continued with the same degree of energy as it has during the past season, the 1st July, 1878, will witness the canal open for the passage of tugs, dredges, and the aller class of vessels.

The United States have under construction, but far from completion, an outer har-r on the lake end for the protection of the outlet of the canal, and also to serve as a rbor of refuge. This should be completed as early as possible, as it may be other-se difficult to keep the canal open.

The company will be under the necessity of constructing pile and sheet-pile piers at outlet, and for several hundred feet back into the canal, to prevent the waves from shing down the banks; otherwise, the banks, which appear to withstand very well action of the waves from the tugs, will need no further protection for some time er the canal has become navigable, as may be seen from Colonel Houston's report to Chief Engineer, U. S. A.

The dumping-grounds for scow work are on both sides of the bay, and are far from line of channel. The material in the bay is soft mud, and the slopes to the chan- will have to be very small to prevent sliding of the material into the cut.

In conclusion, I would say that it is possible, when once the water flows through the canal, the mud in the head of the bay, which will be stirred up by the action of boats, will tend to form a cementing material to the sand-banks of the canal that may give a stability which will render other protection unnecessary.

I submit herewith a map showing location and progress of canal, November, 18[illegible], and depth of water in canal and Sturgeon Bay.

I am, most respectfully, your obedient servant,

JOHN NADER,
Civil Engineer, Inspector.

To His Excellency HARRISON LUDINGTON,
Governor of Wisconsin.

Z 7.

IMPROVEMENT OF AHNEPEE HARBOR, WISCONSIN.

Original estimate (1870)	$370,000
Appropriated to 1875	75,000
Revised estimate for completing the harbor (see Report of Chief of Engineers, 1876, Appendix W 7)	95,000
Appropriated since	16,000
Leaving to be appropriated	79,000
Amount required for the fiscal year 1879–'80	25,000

The superstructure over the 7 cribs placed in 1875, in course of construction at the date of the last annual report, was finished in October under contract with Truman & Schrader, of Manitowoc, Wis., and 1[illegible] cords of stone, blasted from the river-bottom and dredged up by the United States dredge, were put into the pile-piers for $1 a cord. One thousand one hundred linear feet of plank walk were laid on the piers. The United States dredge worked 140¾ hours, removing in that time from the channel 3,551¼ cubic yards of broken rock and 2,336 cubic yards of sand, gravel, &c. The whole expense of the dredge during the fiscal year (repairs, expenses, &c.) charged to this appropriation, was $1,308.[illegible] The cost of the rock excavation cannot be yet determined, as the dredging revealed the fact that the rock will have to be reblasted, so as to excavate about 2 feet deeper. This contingency was feared on account of the seam in the rock.

During the winter it was proposed to continue the blasting and removal of rock, but the condition of the ice was such as not to afford the shelter expected from the sea; and the funds on hand were so limited that it seemed best to await a fresh appropriation before recommencing this work, so as to avoid breaking up the party for lack of funds. My assistant, Mr. L. Y. Schermerhorn, who was in local charge of the similar work at Eagle Harbor during the past three years, was sent to this point June 10, and the drilling and blasting have been commenced and will be prosecuted through the present season.

In my last annual report I stated that the site of the bayou had been deeded to the village. I have since ascertained that although the deed was executed, it was never delivered or recorded. This, however, will have no effect upon the harbor, except to prevent the excavation of the bayou, which is now so thoroughly filled up with sand that I am in doubt whether it would pay to again excavate it.

During the fiscal year 1879–'80 the operations proposed are the continuation of the improvement by blasting and removing the rocky bed of the river to 12 feet water, as recommended by the Board of Engineers (see appendix W 7, Report of Chief of Engineers for 1876), and such repairs as may be necessary to preserve the piers.

Money statement.

July 1, 1877, amount available	$6,997 05	
Amount appropriated by act approved June 18, 1878	8,000 00	
		$14,997 05
July 1, 1878, amount expended during fiscal year	5,486 11	
July 1, 1878, outstanding liabilities	253 80	
		5,739 91
July 1, 1878, amount available		9,257 14
Amount (estimated) required for completion of existing project		$79,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1880.		25,000 00

List of materials used and work done by contract at Ahnepee Harbor, Wisconsin, in the year 1877.

Materials for 7 superstructures, each 50′ x 20′, 1,100 linear feet of plank walk, and refilling pile-piers.	Price.	Quantity.	Amount.
Pine timber, framed, 12″ x 12″ ... linear feet	$0 20	10,557	$2,111 40
Pine plank ... feet, board-measure	2 00	3,456	6 91
Laying plank ... do	1 00	10,008	10 01
Drift-bolts, 1⅛″ square ... pounds	03	18,380.55	551 41
Screw-bolts ... do	04	325	13 00
Brush ... cords	2 25	71.63	161 17
Spikes, wrought ... pounds	04	375	15 00
Stone, handled* ... cords	1 25	230.89	288 61
Stone, broken ... days	1 50	6	9 00
Stone, scowing (100 cords by hired labor) ... cords	1 00	187.5	187 50
Total			3,354 01

*38.4 cords of stone placed in the superstructures by C. G. Boalt, is not included in the above amount.

COMMERCIAL STATISTICS.

Name of harbor, Ahnepee, Wis.; collection-district, Milwaukee, Wis.; nearest light-house, Twin River Point.

Arrivals and departures of vessels during the year ending December 31, 1877.

	Arrivals.			Departures.		
	No.	Tonnage.	Crew.	No.	Tonnage.	Crew.
Steamers	105	37,611	2,205	105	37,611	2,205
Sailing-vessels	424	36,041	2,629	424	36,041	2,629
Total	529	73,652	4,834	529	73,652	4,834

Exports during the year ending December 31, 1877.

Bark ... cords	2,216	Lumber ... feet, board-measure	200,000
Barley ... bushels	20,000	Peas ... bushels	2,000
Barrel-hoops ... number	100,000	Posts ... number	119,425
Brick ... number	15,000	Rye ... bushels	500
Butter ... tons	70	Rags ... bales	856
Eggs ... dozen	3,000	Railroad-ties ... number	264,116
Fish ... packages	2,500	Shingles ... number	575,000
General merchandise ... tons	500	Wheat ... bushels	175,000
Hogs dressed ... number	400	Leather ... sides	2,000
Ice ... tons	2,200	Wood ... cords	2,217

Imports during the year ending December 31, 1877.

Beef	barrels..	90	Reapers	number..	[illegible]
Flour	barrels..	2,500	Salt	barrels..	[illegible]
General merchandise	tons..	1,600	Seeders	number..	5
Hay-rakes	number..	75	Sugar	barrels..	[illegible]
Hides	number..	1,000	Threshers	number..	5
Plows	number..	300	Whisky	barrels..	[illegible]
Pork	barrels..	250			

The above information was obtained from Conway Brothers, Decker & Co., S. Pe[illegible], and others.

Z 8.

IMPROVEMENT OF TWO RIVERS HARBOR, WISCONSIN.

Original estimate	$265,588
Appropriated since	120,000
Leaving to be appropriated	145,588
Amount required for the fiscal year 1879–'80	40,000

The superstructure and plank walk in progress of construction at the date of the last annual report, by Truman & Schrader, of Manitowoc, Wis., over 6 cribs, sunk in 1875, were completed in October. Three hundred linear feet of pier was decked by hired labor, and soundings were taken through the channel on lines 50 by 20 feet apart. In January an examination by soundings was made of the lake-bottom in the vicinity of the bridge-pier, in order to make a report called for by the Chief of Engineers, which is appended.

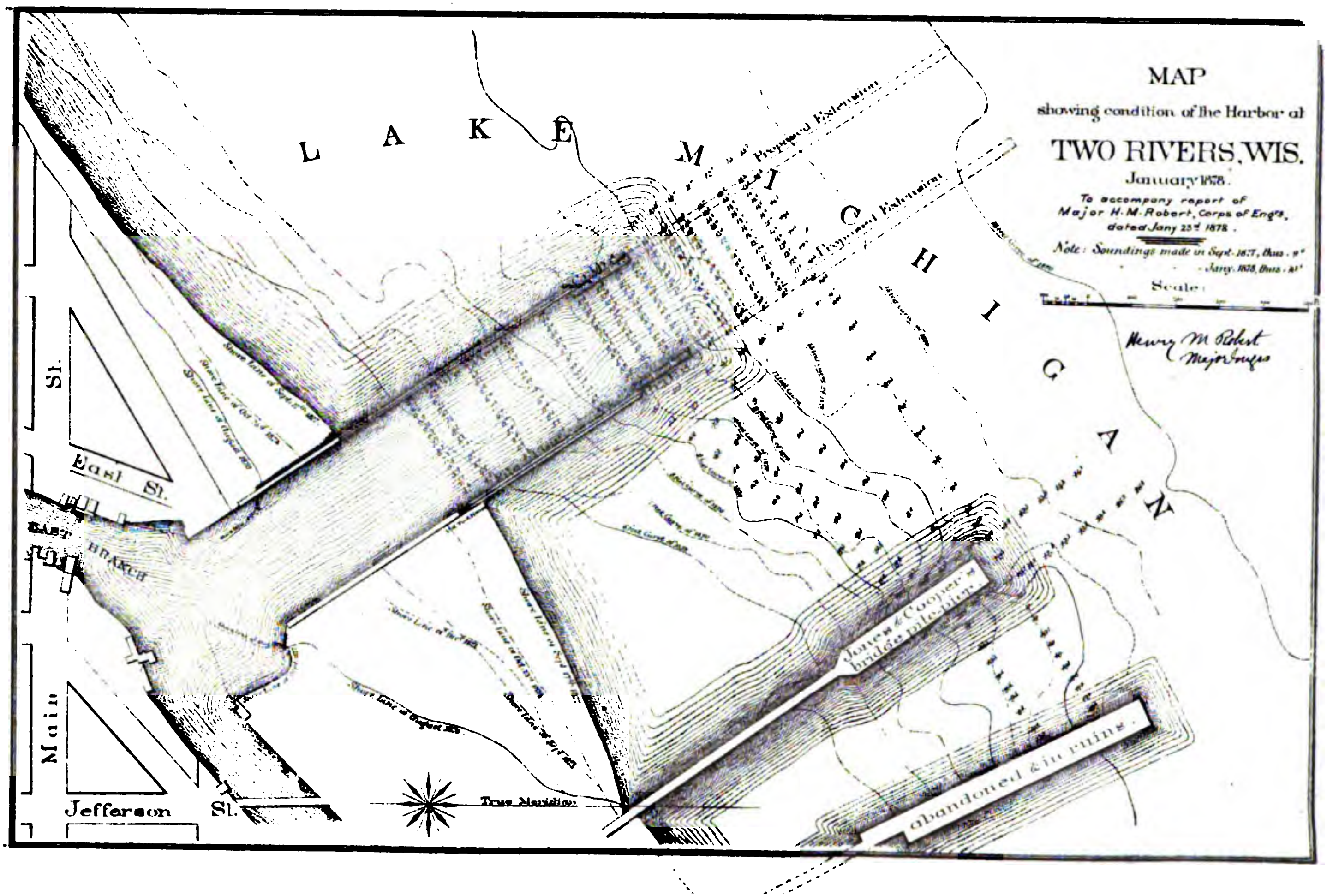
The operations of the present season will comprise the construction of sand-proof lining on the pile-piers, after which the necessary dredging will be done to enable cribs for further pier-extension to be floated out.

The work proposed during the fiscal year 1879–'80, is the further extension of the piers and dredging between them.

The question of accretions forming around the only available pier, the private bridge pier, is becoming of serious importance. Work on the harbor has never yet been sufficiently advanced to permit of its use by even the local commerce, and as the water is shoaling fast around the bridge pier, which it will not pay to extend in view of the approaching completion of a public harbor, it is advisable to complete the government work as soon as possible. This subject is more fully discussed in my special report of January 23, 1878, a copy of which is appended.

Money statement.

July 1, 1877, amount available	$4,969 12	
Amount appropriated by act approved June 18, 1878	10,000 00	
		$14,969 12
July 1, 1878, amount expended during fiscal year		4,951
July 1, 1878, amount available		10,017
Amount (estimated) required for completion of existing project		145,588
Amount that can be profitably expended in fiscal year ending June 30, 1880.		40,000



MAP

showing condition of the Harbor at

TWO RIVERS, WIS.

January 1878.

To accompany report of
Major H. M. Robert, Corps of Engrs,
dated Jany 23rd 1878.

Note: Soundings made in Sept. 1877, Bass. 9
" " " Jany. 1878, Bass. 10

Scale:

Henry M Robert
Major Engrs

REPORT OF MAJOR H. M. ROBERT, CORPS OF ENGINEERS, OF JANUARY 23, 1878.

UNITED STATES ENGINEER OFFICE,
Milwaukee, Wis., January 23, 1878.

GENERAL: In compliance with your instructions, contained in indorsement of January 11 on communication from the Hon. E. S. Bragg (herewith returned), I would respectfully submit the following report upon the recent changes in the vicinity of the harbor at Two Rivers, Wis.

1.—THE NATURE OF THE GOVERNMENT IMPROVEMENT.

In 1870 a survey of the vicinity of this harbor was made, and in 1871 the United States commenced building two piers extending in a southeasterly direction from the mouth of the river into the lake. These piers now average about 1,200 feet in length, almost reaching the 12-foot curve of 1870. They are to be built out 900 feet further to the 18-foot curve of 1870. As now built, except the last 150 feet on each, they are pile-piers, and the sand sifting through them fills up the dredged channel to the outside level whenever the pier is exposed to the full force of the storm. For this reason, I have not thought it advisable, during the last three years, to keep the channel open, as the small appropriations made would thus be expended each year without putting a dollar on the permanent improvement of the harbor. The village of Two Rivers took the very sensible course last summer of doing just what dredging was necessary to keep the channel open for vessels drawing about 7 feet.

The government has not then, either theoretically or practically, made its improvement of the harbor at Two Rivers available. Whenever a crib is to be sunk on extension of the piers, in order to got it into position, it becomes necessary to dredge the channel, which thus, for a time, becomes available for small craft. The steamers all continue to stop at the outside bridge pier, which is private property and located entirely outside of the government improvement, about 700 feet southwest of and parallel to the harbor piers. It is in the vicinity of this bridge pier that the obstruction exists which is complained of in Mr. Bragg's letter.

2.—EFFECT OF BUILDING THE HARBOR PIERS.

I had soundings taken last September, including the space between the harbor piers, and also extending 300 feet beyond these piers, for a width of 380 feet. The grounding of the vessels alluded to in Mr. Bragg's letter occurred in the next month, October, close by the private bridge pier. After receiving your instructions, I had such soundings made in the neighborhood of this pier, and between it and the harbor piers, as the weather and floating ice would permit of. By comparing these two series of soundings with those of the previous years, and especially with the thorough survey made in 1870, just prior to the commencement of the improvement, it will be noticed that the shore-line has been making out just outside of the harbor piers, it having advanced on the east side of the piers 240 feet in the 7 years, or two-thirds the distance between the old shore-line and the curve of 6 feet depth, and on the west side having advanced 600 feet or seven-eighths of the same distance (see inclosed tracing). This made land on the west side of the piers is in the form of a right-angled triangle, the base along the west pier being 600 feet long, and the altitude, 700 feet long, being the present shore-line between the harbor piers and the bridge pier, the apex being at the bridge pier.

The shore-line does not appear to have been affected beyond the bridge pier, a distance of 700 feet. But while at the present shore-line near the harbor pier there has been a deposit of 4 feet on the east side and 5 on the west, the deposit is not so great as we go farther into the lake, it being not over one-half as much at the 12-foot curve. Though the data on hand are not sufficient to decide the matter, yet I should infer that the deposit at the 18-foot curve, the proposed limits of the piers, is less than 1 foot deep, the effect being to make the bed of the lake near the piers steeper, or to reduce the distance from the shore to, say, the 12-foot curve.

Now, at the foot of the bridge pier the shore-line is the same as it was in 1870, and as there is no reason to suppose a change in the law of the deposit (that is, that the deposit is greater at the shore-line, so as to increase the slope of the lake-bed), I cannot see why it is not fully as reasonable to suppose that the construction of the harbor piers ought to increase the depth of water at the head of the bridge pier as to diminish it.

But an examination of the changes in the vicinity of the bridge pier leads me to the opinion that the construction of the harbor piers has had but little to do with these changes. From the tracing inclosed it will be noticed that the shore-lines of all the five different surveys (1870 to 1877) unite at the bridge pier, that appearing to be the limit of the effect of the harbor piers so far. If we notice the general direction of the shore-line and of the 6 and 12 feet curves of 1870 (before the harbor piers were commenced) we will see that the bridge pier did not reach the natural 12-foot curve, there being only 12 feet of water 100 feet beyond the pier on the line of its extension at that time, and last week there was exactly to the inch the same depth of water there. The vessels that ran aground just outside of this bridge pier in October last drew from 11½ to 12½ feet, I am informed, and would probably have grounded under similar circumstances in 1870. The sort of "bay" at the head of this pier is unnatural, and is evidently formed by the disturbance of the sand consequent on the steamers landing at the pier. A severe storm would doubtless level the sand, and thus fill up this little bay. As corroborative testimony to the correctness of this view we have the statements of two persons who would be most apt to know the facts—Captain Sweeny, of the large steamer Chicago, which stops at this port every other day during the season of navigation, and Mr. Evans, the agent in charge of the bridge pier. Captain Sweeny says that changes in depth are constantly occurring at Two Rivers, and that 8 or 9 years ago the water was shoaler in the vicinity of the bridge pier than it was during the season of 1877. Mr. Evans says that it was shoaler there 10 or 12 years ago than it was last year or is at present. If, then, the same difficulty has heretofore occurred, when there were no harbor piers, it seems unnecessary to make the harbor piers responsible for the present difficulty, especially as it has been seen that they have not affected the shore-line at that distance, while the place where the difficulty occurred was nearly on the extension of the bridge pier, and is out farther into the lake than the head of the harbor piers.

But while, in my judgment, the construction of the harbor piers had very little or nothing to do with this trouble about landing at the bridge pier, yet this serious difficulty of shoal water exists, and is an argument for prosecuting the work with more energy, especially as the improvement in progress makes it impossible to get any parties to expend money in improving and extending the bridge pier, when its future use is so uncertain.

The first three years Congress appropriated $25,000 annually, and the next two years $15,000 each, giving an annual average of $21,000 for five years. The next year the appropriation was $5,000 and last year nothing. Of the original estimate there remains to be appropriated the sum of $155,588. The harbor will be worth nothing, except for very small sailing vessels, until the piers are extended from 400 to 500 feet farther, the pile-piers provided with a sand-proof lining, and the channel dredged. The cost of this will be about $100,000, and until this additional amount is expended upon this harbor it cannot be said to be opened. The economy of appropriating a large sum at one time is so fully shown by Major Houston in his report on this very harbor (page 202, Report of Chief of Engineers for 1873) that it is needless for me to do more than refer to it.

Under the circumstances, I would respectfully recommend that $40,000 be appropriated for the harbor at Two Rivers, Wis., for the fiscal year ending June 30, 1879, instead of $20,000 recommended in my annual report of last July.

Very respectfully, your obedient servant,

HENRY M. ROBERT,
Major of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

List of materials used and work done at Two Rivers Harbor, Wis., during the season of 1877.

Materials and work for six superstructures, 1,500 feet of plank walk decking, 300 feet of pier, and survey.	Price.	Quantity.	Amount.	Done by—
Superstructures:				
Pine timber, framed, 12″ by 12″ ....linear feet..	$0 19	8, 236	$1, 564 84	Contract.
Drift-bolts ....pounds..	03	13, 294. 09	398 82	Do.
Screw-bolts ....do....	05	89. 6	4 48	Do.
Stone ....cords..	5 30	263½	1, 396 54	Do.
Brush...do....	2 50	33. 1	82 75	Do.
Plank walk:				
Pine plank.......................feet, board-measure..	7 00	14, 112	98 78	Do.
Laying plank ....do....	1 00	14. 112	14 11	Do.
Spikes, cut ....pounds..	03	550	16 50	Do.
Spikes, wrought.................................do....	04	25	1 00	Do.
Decking and survey:				
Pine plank.......................feet, board-measure..	10 00 to 12 00	13, 104	154 56	Hired labor.
Spikes, wrought ....pounds..	03. 3	600	19 80	Do.
Spikes, cut.....................................do....	03½	25	88	Do.
Labor (exclusive of overseer)......................	....	....	130 42	Do.
Total..	....	....	3, 883 48	

Average cost of superstructures, each	$574 57
Average cost of superstructures, per linear foot..............................	11 49

COMMERCIAL STATISTICS.

Name of harbor, Two Rivers, Wis.; collection-district, Milwaukee, Wis.; nearest light-house, Twin River Point, Wis.

Arrival and departure of vessels during year ending December 31, 1877.

	Arrivals.			Departures.		
	Number.	Tonnage.	Crews.	Number.	Tonnage.	Crews.
Steamers..............................	280	140, 000	8, 960	280	140, 000	8, 960
Sailing-vessels.......................	120	10, 000	600	120	10, 000	600
Total.................................	400	150, 000	9, 560	400	150, 000	9, 560

Exports for year ending December 31, 1877.

Doors, blinds, and sash...No..	22,000	Hair .... pounds..	6,0
Lumber .... feet, b. m..	6,000,000	Wooden ware ....dozen..	30,0
Lath................... number..	3,000,000	Chairs ....dozen..	5,0
Pickets .... number..	20,000	Grain ....bushels..	40,0
Railroad-ties ....number..	20,000	Slabs........................cords..	5,0
General merchandise....tons..	3,000	Wood ....cords..	4,0
Fish.................packages..	2,000	Empty barrels........number..	4,0
Hay.......................tons..	200	Sundries..................pounds..	35,0
Leather.............. pounds..	970,000	Furniture .... packages..	15,0
Fresh fish............pounds..	450,000		

Imports for year ending December 31, 1877.

Bark ....cords..	5,000	Hides, green ....bundles..	10,0
Whitewood..............cords..	450	Salt .... barrels..	[illegible]
Lumber ....feet, b. m..	800,000	Flour ....barrels..	2,5
Hard-wood lumber feet, b. m..	400,000	Grain .... bushels..	6,0
Shingles ....number..	500,000	General merchandise.....tons..	5,0
Hides, dry ....number..	12,000		

This information was obtained from the Two Rivers Manufacturing Company.

Z 9.

IMPROVEMENT OF MANITOWOC HARBOR, WISCONSIN.

Original and subsequent estimates to get 18 feet water..................	$248,182 54
Appropriated since..	226,500 00
Leaving to be appropriated...	21,682 54
Amount required for the fiscal year 1879–'80	21,682 54

The repair-work in progress at the date of the last annual report was completed, and a series of soundings was taken through the channel to a point 200 feet east of the pier-heads. (For details of repairs see table.

The operations of the present season will comprise further extension of the piers by placing 4 new cribs, refilling the piers, and such incidental repairs as may be found necessary.

During the fiscal year 1879–'80, it is proposed to still further extend the piers to 18 feet water, and to do such dredging as may be necessary. If the whole amount asked for be appropriated in one sum this harbor will be finished within the estimated cost notwithstanding that a good deal of repair-work had to be done by reason of the slowness of the appropriations.

The recommendation contained in my last annual report in reference to the importance of the early completion of this excellent harbor is respectfully renewed. As will be seen by reference to that report the position of Manitowoc Harbor gives it a more than local importance, and makes its completion a matter in which the whole commerce of the lake is interested. (See Report of the Chief of Engineers, 1877, page 863.)

Money statement.

July 1, 1877, amount available..................................	$2,131 69	
Amount appropriated by act approved June 18, 1878...........	15,000 00	
		$17,131 69
July 1, 1878, amount expended during fiscal year........................		2,062 40
July 1, 1878, amount available..		15,069 29
Amount (estimated) required for completion of existing project..........		21,682 54
Amount that can be profitably expended in fiscal year ending June 30, 1880.		21,682 54

List of materials used and work done at Manitowoc Harbor, Wisconsin, during the working season of 1877, by hired labor and purchase in open market.

Materials.	Quantities.	Price.	Amount.
Pine timber	13,153 feet, board-measure	$12	$157 84
Pine plank	26,816 feet, board-measure	$10 to $12	292 62
Stone	521.63 cords	$5	2,608 15
Brush	127 cords	$2	254 00
Spikes	1,593 pounds	0.03\frac{3}{10}$ to 0.03\frac{7}{10}$	54 98
Drift-bolts	1,237 pounds	$0.03¼	40 20
Screw-bolts	866 pounds	$0.04½ to $0.05¼	41 82
Washers, cast and wrought	196 pounds	$0.03 to $0.08	6 43
Cartage	1	$0.50	50
Labor (exclusive of overseer)		$1.50 to $2.50	236 30
Total			3,692 84

NOTE.—The north and south piers were refilled as far as the funds available would permit. The wood-work of both piers was put in good repair, 70 linear feet of the south face of the superstructure of the south pier was rebuilt 4 courses in height, and the outer 250 linear feet of each pier was decked with 3-inch plank. Of the above amount, 60 per cent. was expended on the north pier, and 40 per cent. on the south pier.

COMMERCIAL STATISTICS.

Name of harbor, Manitowoc, Wis.; collection-district, Milwaukee, Wis.; nearest light-house, Manitowoc, Wis.

Arrivals and departures of vessels during the year ending December 31, 1877.

	Arrivals.			Departures.		
	No.	Tonnage.	Crews.	No.	Tonnage.	Crews.
Steamers	206	137,915	6,052	207	137,941	6,045
Sailing-vessels	379	20,168	1,094	380	19,935	1,099
Total	585	158,083	7,146	587	157,876	7,144

Exports for year ending December 31, 1877.

Lumber ft., b. m.	150,000	Wheat bushels	220,000
Posts No.	28,000	Brick No.	200,000
Flour barrels	45,000	General merchandise tons	12,000
Feed tons	2,000	Butter tons	400
Hay tons	3,200	Peas barrels	10,000
Ice tons	15,000	Railroad-ties No.	24,000
Leather packages	15,000	Shingles No.	800,000
Wood cords	16,000	Eggs doz.	60,000

Imports for year ending December 31, 1877.

General merchandise tons	10,000	Iron tons	600
Salt barrels	3,000	Bark cords	1,000
Coal tons	500	Plaster, rock tons	1,200
Lumber ft., b. m.	2,400,000	Fish pounds	36,000
Shingles No.	6,162,000		

There were built 4 vessels, and 19 vessels repaired.

The above information was obtained from George B. Burnet, deputy collector of customs.

Z 10.

IMPROVEMENT OF SHEBOYGAN HARBOR, WISCONSIN.

Estimated cost of the improvement	$150,593
Appropriated to date	160,591

Additional outlay has been rendered necessary by reason of the dec of the oldest part of the superstructure, the necessity for dredging, a the raising of the lake-bed by deposits near the mouth of the harb from 4 to 6 feet since the work was commenced.

The work of repair (described in my annual report for last year—se Report of Chief of Engineers for 1877, page 364) has been continu from November, 1877, to May 31, 1878, when it was stopped for want o funds; 130 linear feet of old superstructure, built in 1860, on the north pier was removed and replaced by new, one course below and six above the water's surface. On the same pier, 130 linear feet of foot-walk was laid, 2 feet wide, and other portions of the pier were repaired. On the south pier, superstructure was rebuilt over 138 linear feet of pier, one course below and two above the water's surface; 130 linear feet of old superstructure was removed, and 130 linear feet of foot-walk laid.

An unusually heavy gale from the northeast having caused an obstruction in the channel by blowing the beach-sand into it, the United States dredge was sent to this harbor from Port Washington in May, 1878; the expense of towing her to Sheboygan and back and of tending her with a steam-tug while there being defrayed by the city of Sheboygan. The dredge removed 7,117 cubic yards of material from the channel in 13½ working days.

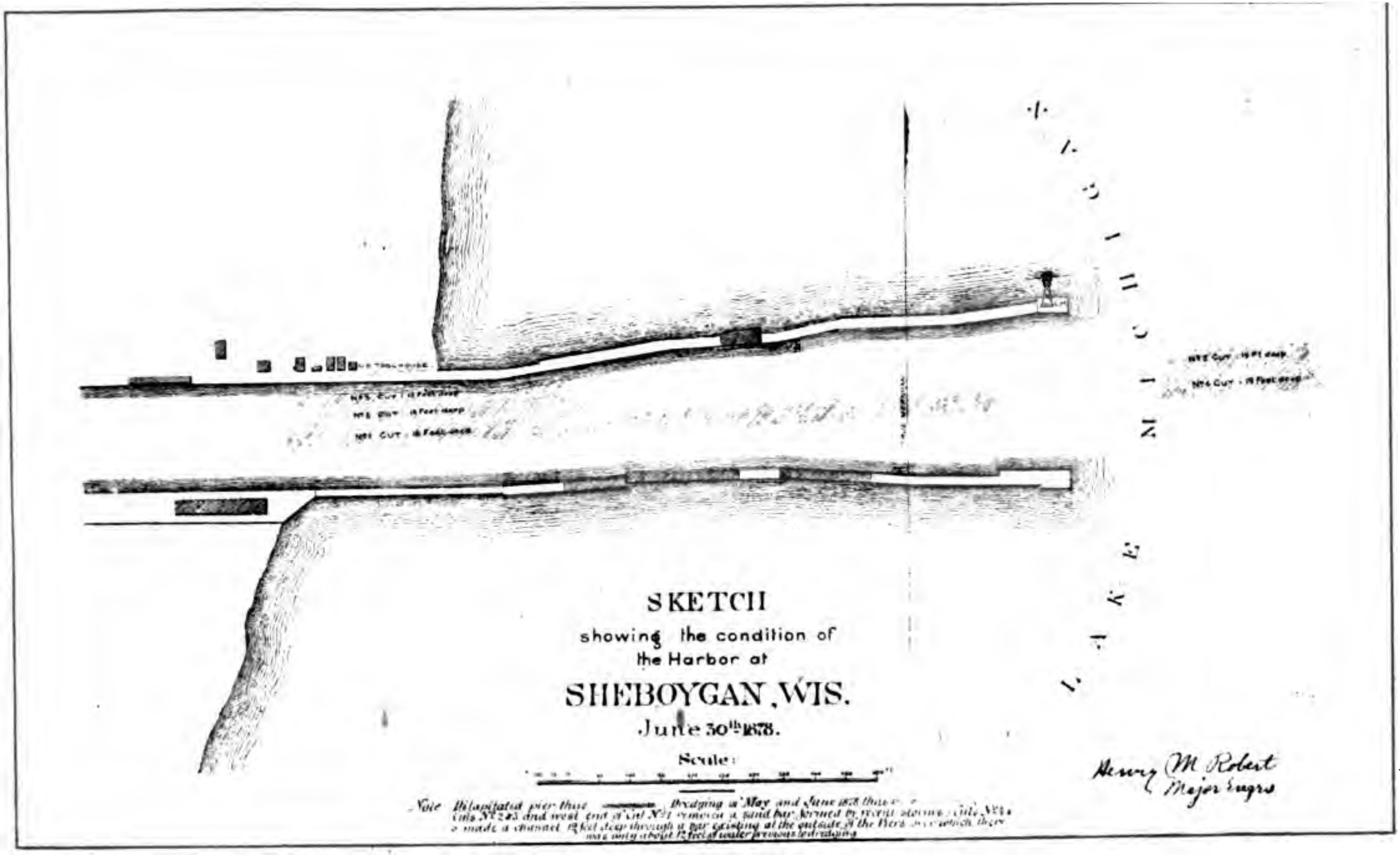
During the present season the repairs will be continued as before, and such dredging done as may be necessary to keep the channel open. Similar work is proposed for the fiscal year 1879–'80. As nearly as can now be estimated it will require about $8,000 more to complete the repair work exclusive of any dredging.

Money statement.

July 1, 1877, amount available	$3,049 24	
Amount appropriated by act approved June 18, 1878	4,000 00	
		$7,049 24
July 1, 1878, amount expended during fiscal year		3,037 66
July 1, 1878, amount available		4,011 5
Amount (estimated) required for completion of repairs and dredging		10,000 0
Amount that can be profitably expended in fiscal year ending June 30, 1880.		10,000 0

List of materials used at Sheboygan Harbor, Wisconsin, during the fiscal year 1877–'78, purchased in open market for repairs of piers.

Materials.		Prices.	Quantities.
Timber	feet, board-measure	$12.75 per M to $14.50 per M.	43,087
Drift-bolts	pounds	Old, reused	7,528
Spikes	do	4½ cents	3,12
Plank	feet, board-measure	$11 per M	1,184



SKETCH
showing the condition of
the Harbor at
SHEBOYGAN, WIS.
June 30th 1878.

Note Dilapidated pier thus ——. Dredging in May and June 1878 thus: Cuts Nº 2 & 3 and west end of Cut Nº 1 remove a sand bar formed by recent storms; Cuts Nº 4 & 5 made a channel 12 feet deep through a bar existing at the outside of the Piers over which there was only about 12 feet of water previous to dredging

Henry M Robert
Major Engrs

COMMERCIAL STATISTICS.

Name of harbor, Sheboygan, Wis.; collection-district, Milwaukee, Wis.; nearest light-house (on harbor pier), Sheboygan, Wis.

Arrival and departure of vessels for year ending December 31, 1877.

	Arrivals.			Departures.		
	No.	Tonnage.	Crews.	No.	Tonnage.	Crews.
Steamers	840	495,049	25,802	840	495,049	25,802
Sailing-vessels	459	27,197	1,491	468	27,526	1,507
Total	1,299	522,246	27,293	1,308	522,575	27,309

Exports for year ending December 31, 1877.

Wheat ... bushels..	650,000	Flour ... barrels..	2,100
Feed ... tons..	180	Potatoes ... bushels..	4,000
Hay ... tons..	2,000	Fish ... packages..	13,300
General merchandise..tons..	15,200	Lime ... barrels..	19,000
Bricks ... number..	1,200,000	Stone ... cords..	800
Cattle ... head..	800	Pork-barrels ... number..	18,500

Imports for year ending December 31, 1877.

Lumber, ft., board-measure..	9,500,000	Lath ... number..	2,000
Shingles ... number..	8,000	Posts ... number..	7,500
Coal ... tons..	13,500	Plaster-rock ... cords..	3,500
General merchandise..tons..	11,400	Salt ... barrels..	13,200
Pickets ... number..	75,000	Bark ... cords..	6,000
Cement ... barrels..	1,500		

The above information was obtained from custom-house, steamboat office, and various mill-owners.

Z II.

IMPROVEMENT OF PORT WASHINGTON HARBOR, WISCONSIN.

Original estimate	$154,527 17
Appropriated since	101,000 00
Leaving to be appropriated	53,527 17
Amount required for the fiscal year, 1879-'80	25,000 00

The area of this harbor will be doubled without any increase in the estimate, under the modification of the plan which I proposed, (see Report of the Chief of Engineers, 1876, Part 2, page 379), and which was approved by the Chief of Engineers, June 7, 1877.

During the past fiscal year the excavation of the north basin was commenced by the United States dredge, which was removed to this harbor as soon as she had finished removing the excavated rock from the harbor at Ahnepee, beginning work July 23, and leaving off November 30. During this time she worked $72\frac{6}{10}$ days of 10 hours each, and lost $39\frac{4}{10}$ days, removing 45,232 cubic yards of material, an average of 403.85 yards per working day, or 623.03 yards for each day worked. Her expenses were $4,484.05, her repairs cost $1,195.22, total $5,679.27, from which deducting the value of fuel on hand at close, $92.75, leaves the net expenses $5,586.52, an average of $49.88 per day or 10.12\frac{35}{100}$ per cubic yard. The contract prices paid at this harbor were as follows: in 1872, 0.49\frac{11}{100}$; 1873, 0.56\frac{1}{2}$; 1874, 0.36\frac{21}{100}$; 1875, 0.34\frac{6}{10}$ per cubic yard.

From the channel between the piers were removed 3,262 cubic yards of material; and repairs were made to the superstructure of the outermost crib of the north pier at a cost of $125.93.

Work by the United States dredge was recommenced June 17 last, and by the end of the month 1,983 cubic yards of material had been removed from the basin. This excavation will be continued as long as funds will permit, and will be renewed with the appropriation asked for the fiscal year 1879–'80, together with such repairs to the piers and revetment as may be necessary.

Money statement.

July 1, 1877, amount available	$7,545 18	
Amount appropriated by act approved June 18, 1878	5,000 00	
		$12,545 1
July 1, 1878, amount expended during fiscal year	7,113 83	
July 1, 1878, outstanding liabilities	146 53	
		7,260 3
July 1, 1878, amount available		5,284
Amount (estimated) required for completion of existing project		53,527 1
Amount that can be profitably expended in fiscal year ending June 30, 1880		25,000

COMMERCIAL STATISTICS.

Name of harbor, Port Washington, Wis.; collection-district, Milwaukee, Wis.; nearest light-house, Port Washington, Wis.

Arrivals and departures of vessels during the year ending December 31, 1877.

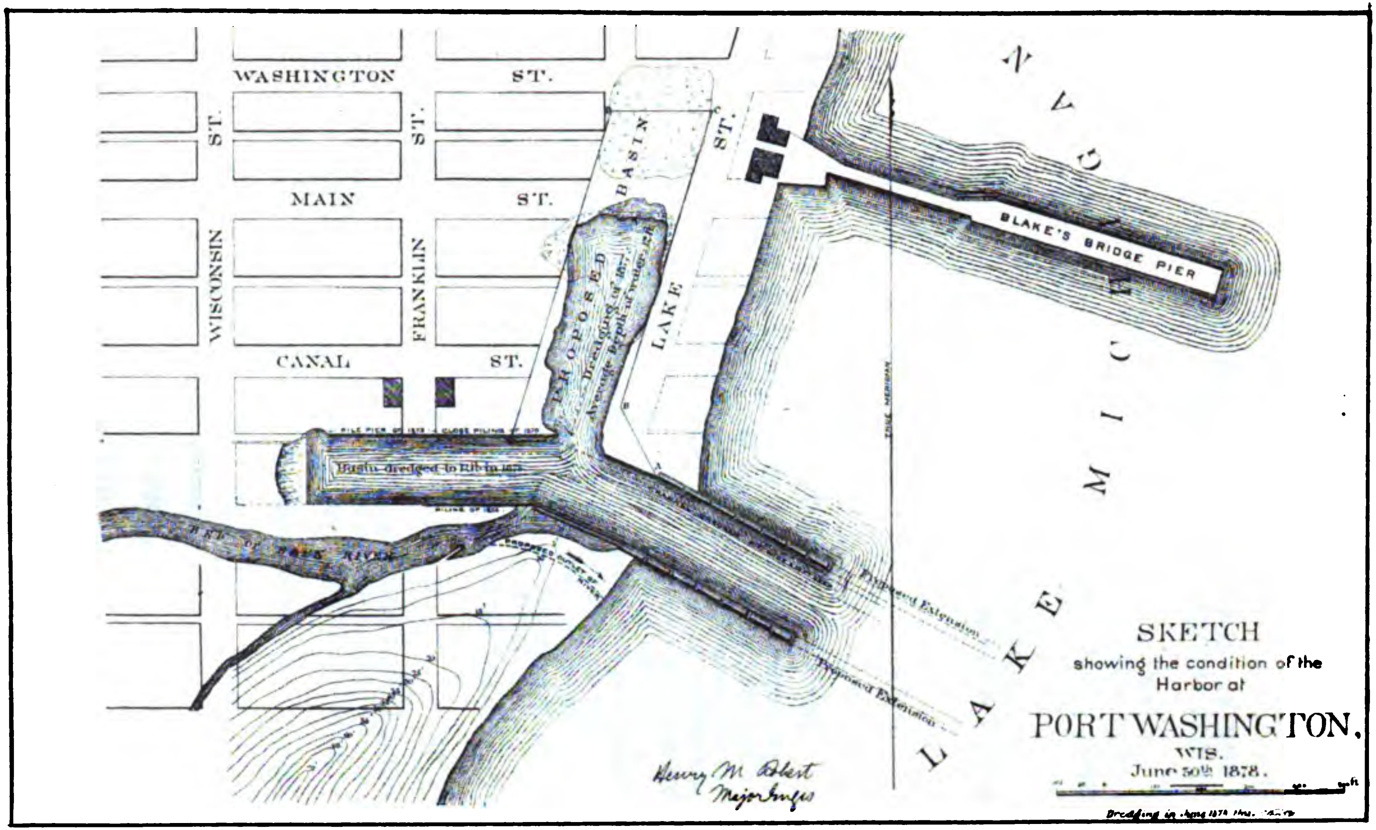
	Arrivals.			Departures.		
	No.	Tonnage.	Crew.	No.	Tonnage.	Crew.
Steamers	490	171,500	8,460	490	171,500	8,4
Sailing-vessels	128	7,680	512	126	7,560	5
Total	618	179,180	8,972	616	179,060	8,9

Exports for the year ending December 31, 1877.

Pork	barrels	500	Brick	Number	560,000
Flour	barrels	8,500	Wheat	bushels	70,000
Empty pork-barrels		8,000	Malt	bushels	50,000
Plows	Number	150	General merchandise	tons	150
Hay	tons	40	Fish	fresh, boxes	200
Lime	barrels	100,000	Castings	tons	642

Imports for the year ending December 31, 1877.

Lumber	feet, board-measure	5,031,085	Seeders	Number	120
Lath	Number	1,830,000	Coal	tons	682
Shingles	Number	3,401,365	Land-plaster	tons	100
Salt	barrels	550	Iron	tons	650
Molding-sand	tons	150	General merchandise	tons	125
Reapers	Number	410	Coke	tons	152



SKETCH

showing the condition of the
Harbor at

PORT WASHINGTON,

WIS.

June 30th 1878.

Henry M. Robert
Major Engrs

APPENDIX A A.

ANNUAL REPORT OF MAJOR D. C. HOUSTON, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1878.

UNITED STATES ENGINEER OFFICE,
Milwaukee, Wis., July 10, 1878.

GENERAL: I have the honor to transmit herewith annual reports for the works in my charge for the fiscal year ending June 30, 1878.

I am, general, very respectfully, your obedient servant,

D. C. HOUSTON,
Major of Engineers, U. S. A.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

A A 1.

IMPROVEMENT OF MILWAUKEE HARBOR, WISCONSIN.

During the year the rebuilding of the timber superstructure for a length of 1,130 feet was completed; the crib-wing at the inner end of the south pier for a distance of 60 feet was repaired; the timber superstructure at the inner end of the north pier for a distance of 70 feet was repaired; and the stone superstructure on north pier was extended 98 feet, making a total length of stone superstructure of 663 feet.

The piers were protected from collision by vessels by a pile protection of 266 feet, making a total length of pile protection of 826 feet.

The appropriation of $15,000 by act of Congress approved June 18, 1878, will be applied to complete the stone superstructure of the north pier as far as possible. There remains to be built 480 feet.

I inclose a report from Mr. W. H. Hearding, assistant engineer, giving an account of work, commerce of port, &c.

Estimated cost of work as now being carried on	$120,000 00
Appropriated since	66,000 00

The above estimate contemplated replacing the old superstructure on both piers by dry stone masonry. The superstructure of the south pier having been replaced in 1877 by timber, the estimate for completion is reduced to $15,000.

This does not contemplate the pier extension which will eventually be needed.

Amount expended to date on present project	$48,910 58

Money statement.

July 1, 1877, amount available	$18,027 20	
Amount appropriated by act approved June 18, 1878	15,000 00	
		$33,027 20
July 1, 1878, amount expended during fiscal year		15,937 78
July 1, 1878, amount available		17,089 42
Amount (estimated) required for completion of existing project		15,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1880.		15,000 00

REPORT OF MR. W. H. HEARDING, ASSISTANT ENGINEER.

UNITED STATES ENGINEER OFFICE.
Milwaukee, June 30, 1878.

SIR: The following report upon the harbor of Milwaukee, Wis., for the fiscal year ending June 30, 1878, is respectfully submitted:

The balance of the appropriation of August 14, 1876, in amount $21,000, became available in April, 1877. This sum was applied to cutting down the superstructure of the section of the south pier built in 1854; in making necessary repairs; in building stone superstructure and laying pavement between walls of stone superstructure for the entire length built, and driving guard-piles.

At the date of report of June 30, 1877, a section of the superstructure of the south pier 800 feet in length had been cut down and rebuilt to a height of 3½ feet. The remaining portion of the entire section, 331.3 feet long, was subsequently cut down and the whole length of the section (in all 1,131.3 feet) was rebuilt to an average height of new superstructure of 4 feet 3 inches. The wing at the west end of the south pier was substantially repaired for a length of 68 running feet. At the west end of the north pier the superstructure of the revetment was cut down and rebuilt for a length of 70 feet and to a width of 8 feet. As a precautionary measure, the safety of the harbor-channel being endangered through the dilapidated condition of the timbers, a section of the old superstructure, 161½ feet in length, was temporarily repaired by bolting new timbers on the channel-wall and securing them with short ties. Ninety-eight and six-tenths feet (running) of stone superstructure was added in extension of the work of 1876. The total length of the stone superstructure completed is [illegible] feet. The length of pile protection given to piers built is 266 feet.

No dredging has been done in the harbor channel since 1874, and the depth of water maintained is somewhat remarkable, the existing channel being 17 feet in depth for the whole distance between the piers; the unusually heavy spring freshets undoubtedly removed a portion of the sedimentary deposit.

The condition of the channel is shown by the accompanying plat of soundings taken May 8, ultimo.

A light-house is located upon the north point of Milwaukee Bay, having a lens of the fourth order; the light is fixed, varied by flashes at intervals of two minutes, and is visible 14 miles.

A beacon-light is placed upon the extremity of the north pier for the guidance of vessels into the harbor. During the past year a steam fog-whistle has also been placed upon the north pier in connection with the beacon-light. During the prevalence of fogs the whistle sounds at intervals of 55 seconds.

For the past two or three years the competition between the railroad and marine interests has reduced the rates of freight to the seaboard, so that in some instances vessel owners have laid up their vessels in preference to keeping them in commission, the freights not being much more than sufficient to pay for running expenses.

The following is a summary of entrances and clearances during the past year:

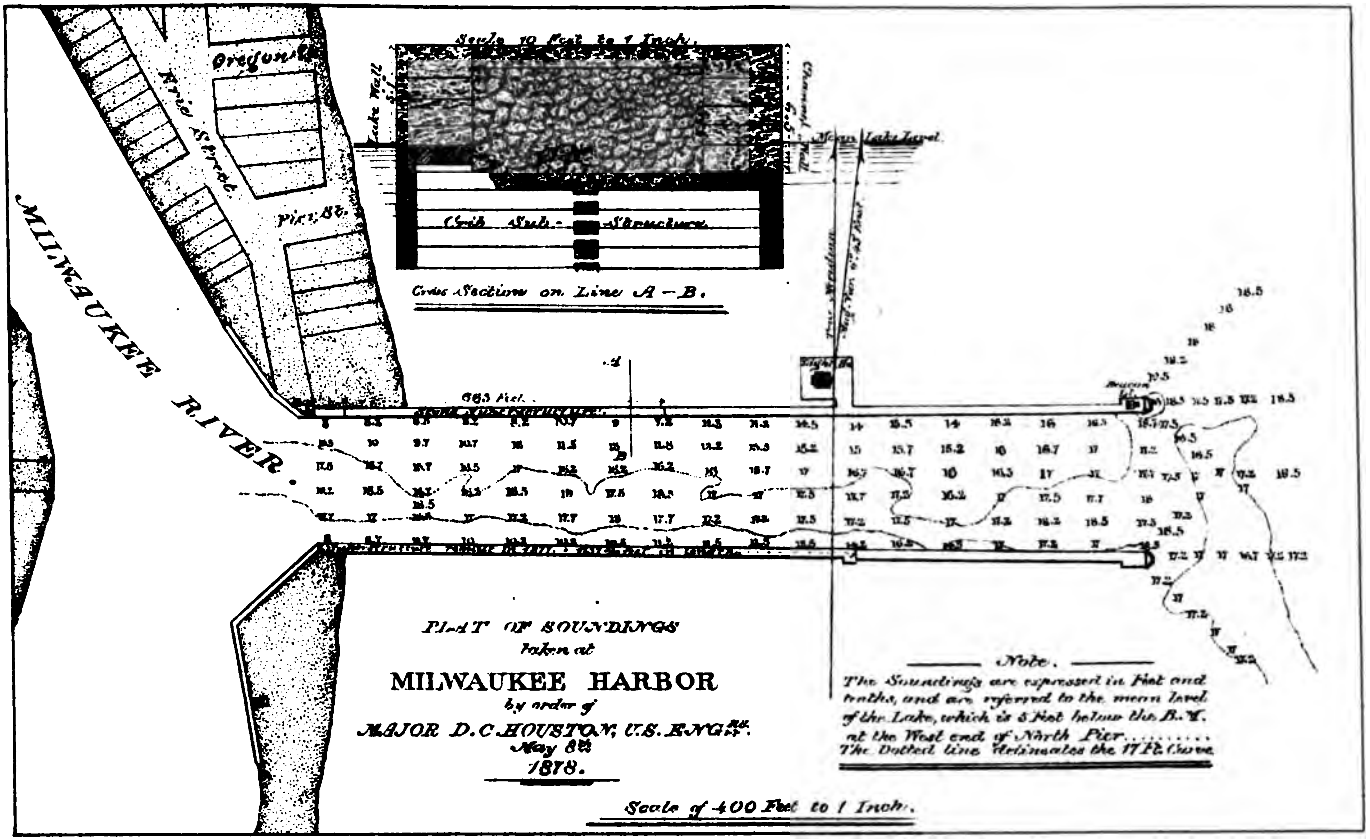
Vessels.	No.	Tonnage.	Men.
Entrances.			
Steamers	3, 241	2, 511, 853	83, 6
Sailing-vessels	4, 519	666, 316	22, 5
Total	7, 760	3, 178, 169	106, 14
Clearances.			
Steamers	3, 244	2, 608, 840	83, 3
Sailing-vessels	4, 527	665, 894	22, 51
Total	7, 771	3, 274, 734	105, 8
Entrances of foreign vessels from foreign ports	51	20, 693	6
Clearances of foreign vessels from foreign ports	50	17, 955	5

Total amount of revenue collected from customs dues at this port of entry, $53,255.97.

I have the honor to subscribe myself, very respectfully, your obedient servant,

W. H. HEARDING,
Assistant Engineer.

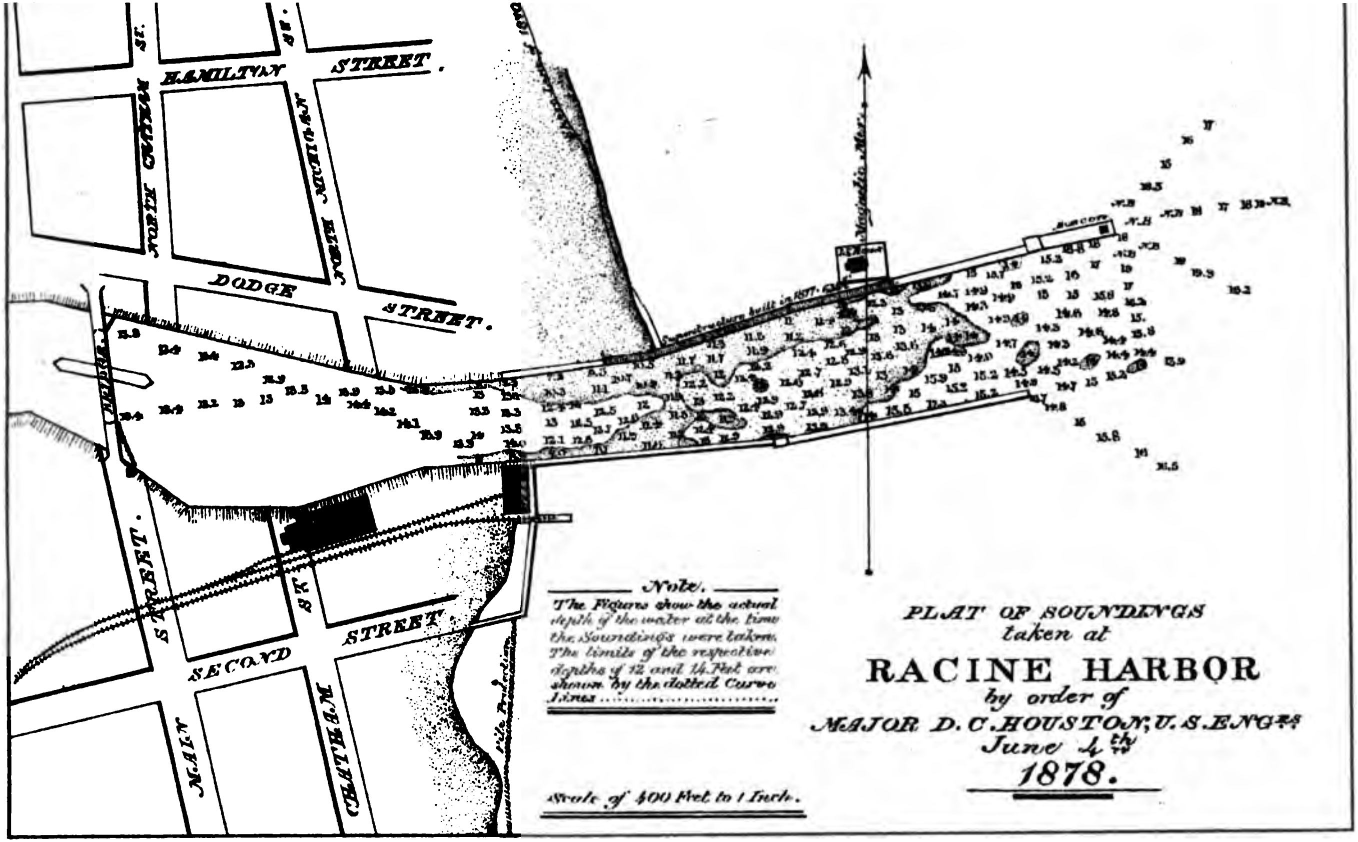
Bvt. Col. D. C. HOUSTON,
Major of Engineers, U. S. A.



PLAT OF SOUNDINGS
taken at
MILWAUKEE HARBOR
by order of
MAJOR D. C. HOUSTON, U.S. ENGRS.
May 8th
1878.

Scale of 400 Feet to 1 Inch.

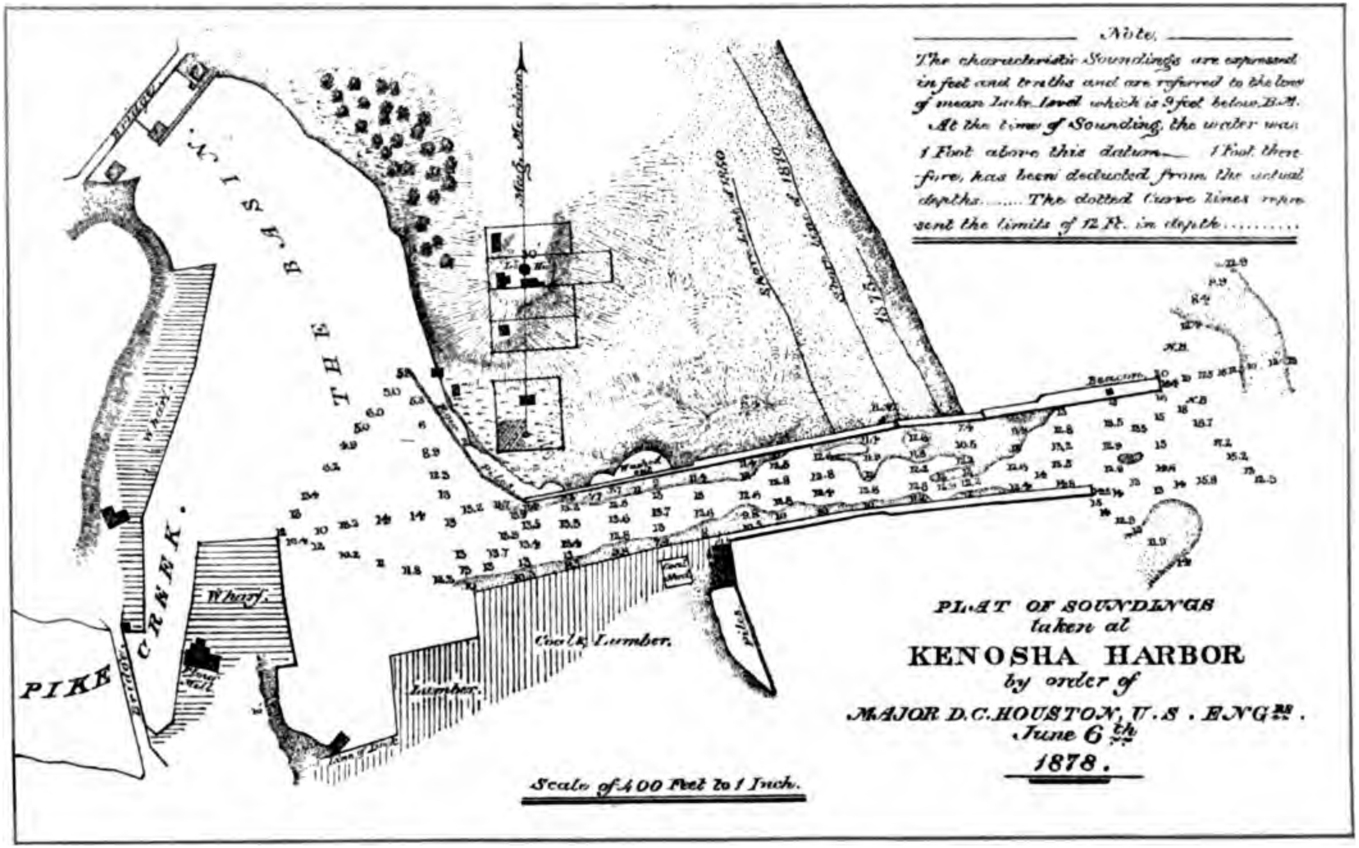
Note.
The Soundings are expressed in Feet and tenths, and are referred to the mean level of the Lake, which is 5 Feet below the B. M. at the West end of North Pier..........
The Dotted line delineates the 17 Ft. Curve.



PLAT OF SOUNDINGS
taken at
RACINE HARBOR
by order of
MAJOR D. C. HOUSTON, U. S. ENGrs
June 4th
1878.

Note.
The Figures show the actual depth of the water at the time the Soundings were taken. The limits of the respective depths of 12 and 14 Feet are shown by the dotted Curve Lines ……………………

Scale of 400 Feet to 1 Inch.



Note.

The characteristic Soundings are expressed in feet and tenths and are referred to the low of mean Lake level which is 9 feet below B.M. At the time of Sounding, the water was 1 Foot above this datum — 1 Foot there-fore, has been deducted from the actual depths....... The dotted Curve lines represent the limits of 12 Ft. in depth.........

PLAT OF SOUNDINGS
taken at
KENOSHA HARBOR
by order of
MAJOR D. C. HOUSTON, U. S. ENG^{RS}.
June 6th
1878.

dredge. This does not seem to have reformed to any great extent since that time; but until the piers are extended farther lakewards it is liable to form again at the recurrence of storms.

From information collected upon the subject, it appears that the commerce of Kenosha has undergone but little change since the date of the last annual report. The exports are stated to have been as follows:

Of oats, 45,000 bushels; flaxseed, 5,000 bushels; tow, 200 tons; wool, 100,000 pounds; leather, 175,000 pounds; pressed hay, 1,200 tons; fish, 500,000 pounds.

Imports.—Coal, 6,100 tons; wood, 3,500 cords; salt, 1,100 barrels; tan-bark, 3,000 cords; pig-iron, 1,800 tons; bar-iron, 1,500 tons; hides, 25,000; lumber, hard and soft, 16,000,000 feet, board-measure.

Number of arrivals of steamers and sailing-vessels, 650; of departures, the same.

The light-house is situated on the north side of the harbor-channel, and is 470 feet distant therefrom. The light is fixed, varied by flashes at intervals of 1 minute and 30 seconds. The lens is of the fourth order. The light is visible 14 miles. A beacon-light is also placed at the eastern extremity of the north pier.

Kenosha is in the collection-district of Milwaukee, which is the nearest port of entry.

I have the honor to subscribe myself, very respectfully, your obedient servant,

W. H. HEARDING,
Assistant Engineer.

Bvt. Col. D. C. HOUSTON,
Major of Engineers, U. S. A.

A A 4.

IMPROVEMENT OF FOX AND WISCONSIN RIVERS.

The work of improving these rivers has been prosecuted in accordance with the plan described in former annual reports. The details of the history and condition of the works during the year ending June 30, 1878, and the progress made are given in the accompanying reports of First Lieut. F. A. Hinman, Corps of Engineers, in immediate charge of operations from Portage City to Princeton Lock; Mr. John Pierpont, assistant engineer, in immediate charge of operations from Princeton Lock to Lake Winnebago; and Mr. C. A. Fuller, assistant engineer, in immediate charge of operations from Lake Winnebago to Green Bay.

No work was done on the Wisconsin River during the year, as all the balance available at the commencement of the fiscal year was required to carry out the project of operations for the Fox.

Navigation was kept open on the Lower Fox during the season of 1877, and reopened on April 15, 1878.

The locks and dams on the Upper Fox were all ready for navigation on October 1, 1877. At the close of the fiscal year all of the new work ontemplated at the date of the last annual report was completed.

Navigation is open from Portage City to Green Bay, and it is expected o maintain it during the season for all boats using the river.

The work proposed for the present season, including the whole of the scal year ending June 30, 1879, is as follows:

LOWER FOX.

Rebuilding De Pere Dam. Rebuilding or repair of Lower Appleton Dam. Construction of guard-gates at head of Kaukauna Canal. Repair nd strengthening of canal-banks. Quarrying stone for construction of ew locks.

UPPER FOX.

Construction of one or more permanent dams to replace temporary ams. Widening and deepening channel by dredging. Repairs of locks t Montello and Governor's Bend.

WISCONSIN RIVER.

No work having been done on the Wisconsin River since 1875, an examination was made of the upper section of the river, and it was found that the channel which had been formed by the works of improvement had been maintained. The accompanying report of First Lieut. F. A. Hinman, Corps of Engineers, gives the results of this examination with a list of soundings in channel. Work will be resumed on this improvement.

The present system of ascertaining damages to private property arising from the works of improvement is very tedious and expensive, both to the government and the parties injured. I would respectfully suggest that the matter be taken out of the local State courts, and that the amount of damages be appraised by commissioners appointed directly by the authorities of the United States.

The object of this improvement is to establish a water-route between the Upper Mississippi and the lakes, by which transportation will be cheapened.

The arguments on this subject are fully given in the report of Maj. G. K. Warren, Corps of Engineers, Report of Chief of Engineers for 1[illegible], page 357, and in the report of the Select Committee on Transportation Routes to the Seaboard, United States Senate, 1874.

The amount of tolls collected during the year ending June 30, 1878, is $2,168.99; required to be reported annually by act of Congress approved July 7, 1870.

Estimated cost of work as now being carried on (reports of 1875 and 1876)	$3,745,66[illegible]
Appropriated since	1,020,00[illegible]
Amount expended to date under this estimate	736,2[illegible]

The following papers are submitted with this report:

No. 1. Annual report of Lieutenant Hinman on Wisconsin River.

No. 2. Annual report of Lieutenant Hinman on Fox River, Portage to Princeton Lock.

No. 3. Annual report of Mr. John Pierpont, assistant engineer on Fox River, Princeton Lock to Lake Winnebago.

No. 4. Annual report of Mr. C. A. Fuller, assistant engineer on Fox River, Lake Winnebago to Green Bay.

Money statement.

July 1, 1877, amount available	$145,308 01	
Tolls received and deposited to credit of appropriation	2,312 06	
Amount appropriated by act approved June 18, 1878	250,000 00	
		$397,6[illegible]
July 1, 1878, amonnt expended during fiscal year	108,750 38	
July 1, 1878, outstanding liabilities	5,141 92	
		113,8[illegible]
July 1, 1878, amount available		283,72[illegible]
Amount (estimated) required for completion of existing project		2,725,66[illegible]
Amount that can be profitably expended in fiscal year ending June 30, 1880		750,0[illegible]

WISCONSIN RIVER.

REPORT OF LIEUTENANT F. A. HINMAN, CORPS OF ENGINEERS.

UNITED STATES ENGINEER OFFICE,
Milwaukee, Wis., July 1, 1[illegible].

SIR: In accordance with your order of the 27th of May last, I have the honor to submit the following report of operations on the Wisconsin River improvement for the fiscal year ending June 30, 1878.

Herein I shall designate the first 12 miles of the river below Portage, Wis., as the upper improved section, and the next succeeding 12 miles as the upper partially-improved section of the river.

No field-work has been done since November, 1875, except to take soundings from time to time (about once a year) in the upper improved section.

This year the soundings were extended to include the upper partially-improved section, and a survey, commenced last month by Mr. Ed. C. Hinman, is now is progress over these sections, to show the present condition of the river between banks.

The last soundings were taken by me on the 8th ultimo, from the United States steamer Portage (drawing 27 inches when her wheels are at work). The gauge-reading at Portage on that date was 1.7 feet above zero (zero being low-water of 1872).

A copy of these soundings is appended hereto. The water has been lower since, but no very low-water stage has prevailed for any great length of time thus far this year.

Although it is over two years and a half since any attempt has been made either to maintain the work built or to construct new work, the dams and shore protections (especially those built in 1874 and 1875) are in a remarkably fine state of preservation, with some exceptions.

It is believed that the channel has continued to improve. The soundings of this year are thought to be more uniform than those of former years, the deep "pockets" having been filled up. An inspection of them shows that throughout the upper improved section there was a practical channel from 4 feet to 10¼ feet deep, and in the upper partially-improved section a channel from 3 to 10¼ feet in depth, with one sounding somewhat deeper than 10¼ feet, under a span of the Chicago and Northwestern Railroad Company's bridge at Merrimack, referred to hereafter.

It is significant that there was a better channel by 1 foot in depth in the improved than in the partially-improved section. In the latter there were five bars, with only 3 feet of water over them. It is thought that soundings as good as the above in the improved section, and perhaps better, could be obtained therein at low water, as the above soundings were taken after a rise, which, instead of materially improving the channel, fills it up somewhat as the bars "flat out." On the return to low water the channel is again cut out deeper.

It is believed that a competent pilot would have no trouble with a boat on the improved section at any time. Of course, better soundings would have been obtained had the improvement been complete and intact. It is doubtful if the *Portage* could pass over the partially-improved section at low water, as the *Winneconne* could not a year ago.

There are 86 dams in this portion of the river, 58 of which are in the improved and the balance (28) are in the partially-improved section. Of these, 36 require repairs. Some of these repairs are very insignificant, and none of them may be deemed very extensive, when it is considered how long ago the dams were built, and also how long since they have been neglected. A number need raising here and there. One on Duck Creek Flats has a large hole at and around the shore end of it, which could have been easily avoided if seen to in season.

The following dams should be removed by a dredge, as they obstruct the best location for the channel, *i. e.*, the "timber dam at Portage," referred to in my last annual report (page 890, Report of the Chief of Engineers, 1877, Part II), which I have since seen at low water and find to be mostly of stone: Dam No. 11, 1871, and No. 9, 1872. No. 11 is just below the mouth of the Baraboo River, and No. 9 is at the head of the partially-improved section. Portions of these have already disappeared.

Aside from the above repairs and modifications, the shore-protections need a little work. Two short dams are required at Portage to maintain a better entrance into the guard-lock, and 17 new dams are required to complete the partially-improved section; in all 9,000 linear feet of dams. Snags and leaning timber should also be removed. The latter work will be light, comparatively speaking.

The Chicago and Northwestern Railroad Company has of late been better adapting its bridge (over 1,880 feet long) at Merrimack to the interests of navigation. The entire raft-span (154 feet long) adjoining the draw on the south has been reconstructed of iron and raised 45¼ feet above the lowest water-mark of 1877 at this point, thus affording a clear low-water way 138 feet wide after the piling is removed. The channel was found to be over 10¼ feet deep under this span. The sounding at this point is marked 10.5+ in the list.

It is understood that the company will remove the lowest boom-pier and the temporary piling now under this span, that the balance of the bridge will be built of iron, and that the present draw-span will be made 200 feet long, so as to give two clear water-ways, each over 80 feet wide, for high-water navigation.

Mr. Charles S. Ladd, the company's bridge-tender and gauge-keeper, has informed me in effect that in 1876 the highest water recorded on the gauge at this point was 8.9 feet above the lowest water of 1877, and that since 1874 (inclusive) it has varied each year from that to 4 feet above the lowest water of 1877.

The following are the names of some of the largest boats that ply on the river, and also the heights of the tops of their smoke-stacks above the surface of the water wh light. With water in the boilers and loaded, these heights would be reduced from 6 8 inches.

Portage 3
Winneconne 3
Ellen Hardy 3

It is presumed that larger boats than these will run on the river in due time. M boats will be able to pass under the raft-span at all stages of the river.

The improvement boats are all in fair condition, except one large and one small s which are not worth repairing, and one large and two small scows now underg repairs, which will be completed shortly.

Since 1875 I have had no opportunity to inspect any portion of the river except t above referred to.

I assume that the lower improved and partially-improved sections from Lone R to Boscobel are in as good condition as the aforesaid upper sections.

On page 227, Report of the Chief of Engineers, 1875, Part I, I reported in substa
48,757 linear feet of completed dams.
91,003 linear feet of proposed dams.

139,760 linear feet of total dams.

For bank-protection, $50,000 (estimated cost $2 per linear foot) and 4,500 linear fe of dams to check the supply of sand above Portage.

On page 418, Report of the Chief of Engineers, 1876, Part II, I also reported in substance: Sixty-five thousand nine hundred and seventy-one linear feet of complet dams and spurs, and 4,768 linear feet of completed bank-protection. No work has be done since, as before stated.

I have, therefore, to submit the following:

GENERAL STATEMENT OF WORK REQUIRED TO COMPLETE THE WISCONSIN RIVER IMPROVEMENT.

The 28 miles of improved river must be repaired, and the 18 miles of partially-improved river repaired and completed. The balance of the river (72 miles) must al be completed. In all, 78,789 linear feet of dams must be built, including 500 linea feet required at the guard-lock entrance referred to above, about 20,232 linear feet bank-protection must be constructed and all snags and leaning timber removed.

To do this work, I recommend that when work is resumed a party be organized an employed in a manner similar to that described by me on pages 403 to 409 (inclusiv Report of the Chief of Engineers, 1876, Part II. It should begin at Portage and complete the work as it proceeds down the river.

I respectfully renew my recommendation on page 890, Report of the Chief of Engineers, 1877, Part II, *i. e.*, "on the score of economy, that operations be not resumed this improvement until sufficient funds are available to work on a large scale," n only to construct work, but to maintain it..

Very respectfully, your obedient servant,

F. A. HINMAN,
First Lieutenant, Corps of Engineers.

Maj. D. C. HOUSTON,
Corps of Engineers, U. S. A.

UPPER IMPROVED SECTION, WISCONSIN RIVER.

List of soundings (not reduced) taken June 8, 1878, commencing at guard-lock and ending dam No. 8, 1872.

Number.	Feet.	Number.	Feet.	Number.	Feet.	Number.	Feet.	Number.	Feet.	Number.	Feet.	Number.	Feet.	Number.	Feet.
1	8.5	13	5.5	25	5.5	37	9	49	6.5	61	7.5	73	6	85	[illegible]
2	7.5	14	5.5	26	5.5	38	9.5	50	6.5	62	6.5	74	8	86	[illegible]
3	7.2	15	5.5	27	7.5	39	7.5	51	6	63	5.5	75	7.5	87	[illegible]
4	8.5	16	5.2	28	7.8	40	7	52	5.8	64	6	76	8.2	88	[illegible]
5	7.5	17	7	29	7	41	6.5	53	6.8	65	8	77	8.5	89	[illegible]
6	6	18	10	30	6.5	42	6	54	6	66	9	78	7.5	90	[illegible]
7	5.8	19	9.5	31	8	43	6	55	6.5	67	7	79	7.8	91	[illegible]
8	7	20	8.5	32	7.5	44	5.8	56	6	68	7.5	80	6.5	92	[illegible]
9	9	21	6.8	33	6	45	8	57	5.5	69	6.5	81	5.5	93	[illegible]
10	10.5	22	5	34	5	46	10.5	58	7.5	70	6.5	82	8	94	[illegible]
11	8	23	5.5	35	6	47	10	59	10	71	8	83	8.2	95	[illegible]
12	6.5	24	5	36	6.5	48	8.5	60	8.5	72	7.5	84	7.8	96	[illegible]

List of soundings taken June 8, 1878, *&c.*—Continued.

Number.	Feet.	Number.	Feet.	Number.	Feet.	Number.	Feet.	Number.	Feet.	Number.	Feet.	Number.	Feet.	Number.	Feet.
97	6.5	119	9.5	141	5.5	163	0.5	185	9.5	207	6.5	229	8.2	251	6.5
98	9.5	120	9	142	7.5	164	0.5	186	8	208	8.4	230	8	252	7.5
99	8.5	121	7	143	6.5	165	19.5	187	7.5	209	7.5	231	7.5	253	9.5
100	10	122	6.5	144	4.5	166	17.5	188	7	210	7.5	232	7	254	9.5
101	9.5	123	4.8	145	4.5	167	18	189	8.5	211	7.5	233	9	255	7
102	8.2	124	4	146	6	168	9.5	190	10	212	6.3	234	7	256	5.5
103	7.8	125	4.8	147	7	169	10.4	191	8.5	213	6.5	235	7	257	4.8
104	7	126	6	148	6	170	6.5	192	7	214	8.8	236	7.5	258	5
105	7.5	127	6	149	6.5	171	5.8	193	6.5	215	8.5	237	9	259	7.5
106	8	128	8	150	5	172	9.6	194	10	216	6.5	238	6.8	260	7.5
107	6.5	129	7.5	151	9	173	6.5	195	10	217	6	239	7	261	7
108	6	130	5	152	9	174	5.8	196	9.5	218	6	240	8	262	7.5
109	4.8	131	4.5	153	5	175	6.5	197	9.5	219	7.8	241	8.5	263	6.5
110	5.5	132	4.5	154	6	176	6.5	198	8	220	6.8	242	6.8	264	7
111	6	133	4	155	7	177	7	199	8.5	221	8	243	6.8	265	8.3
112	6.5	134	4.5	156	7	178	7	200	8	222	0	244	8	266	8.5
113	8.8	135	5.5	157	6.5	179	8	201	7.5	223	7.5	245	9.5	267	7
114	7	136	8	158	8	180	8.5	202	8	224	6	246	10.5		
115	6.5	137	8.8	159	6.5	181	7	203	6.5	225	14	247	8.5		
116	4.8	138	8.5	160	6.8	182	6.5	204	6	226	6	248	6.5		
117	9.5	139	6.5	161	8.7	183	9.5	205	6.5	227	7.5	249	7		
118	9.5	140	5.5	162	10	184	8.5	206	6.5	228	7	250	6.5		

UPPER PARTIALLY-IMPROVED SECTION, WISCONSIN RIVER.

List of soundings (not reduced) taken June 8, 1878, *commencing at dam No.* 8, 1872, *and ending at dam No.* 8, 1874, *at Skinner's Bluff.*

Number.	Feet.	Number.	Feet.	Number.	Feet.	Number.	Feet.	Number.	Feet.	Number.	Feet.	Number.	Feet.	Number.	Feet.
1	6.5	41	7.5	81	5.5	121	6	161	8	201	7	241	7	281	6
2	8.5	42	6.5	82	6	122	5	162	5	202	6	242	8	282	5
3	8	43	6	83	7.8	123	5	163	5.5	203	7.5	243	9	283	5
4	10.5	44	6	84	9	124	4.5	164	10	204	9.5	244	7.5	284	4
5	9	45	5.5	85	7.5	125	4	165	8.5	205	8	245	6	285	4
6	8.5	46	7	86	6.5	126	3	166	7	206	7	246	5.5	286	4.5
7	7	47	8.2	87	10	127	3	167	8	207	8	247	5	287	5
8	5	48	8	88	5.5	128	9.5	168	7.5	208	10	248	4	288	5.5
9	4.5	49	7.5	89	8	129	10	169	7.5	209	8.5	249	4.5	289	7
10	4.5	50	7	90	10	130	10	170	8.5	210	9.5	250	4.5	290	8
11	4	51	6.5	91	10	131	7	171	6	211	5	251	5	291	7.5
12	6	52	5	92	10.5	132	6	172	4	212	4.5	252	5	292	6
13	4.5	53	5.5	93	7	133	5	173	3.8	213	4.5	253	4.5	293	4.5
14	4	54	7	94	6	134	5	174	3.5	214	4	254	4.5	294	6
15	4	55	9.5	95	5	135	8	175	3	215	6	255	5	295	6.5
16	3.8	56	9.5	96	4.5	136	10	176	3.5	216	8	256	5	296	4.5
17	8.5	57	10	97	4	137	8.5	177	3.5	217	7.5	257	7	297	3.8
18	3	58	8.5	98	5	138	4.5	178	6	218	6.5	258	6.5	298	3.5
19	3	59	6.5	99	5	139	4.5	179	10	219	6	259	7	299	3
20	3	60	6.5	100	4.8	140	7	180	10	220	5.5	260	7.5	300	3.5
21	4	61	6	101	4.5	141	9.5	181	10	221	5	261	7	301	4
22	4.5	62	6	102	4.5	142	9.5	182	8.5	222	4.8	262	6	302	5.5
23	4	63	5.5	103	4.8	143	9.5	183	10	223	4.5	263	6	303	6.5
24	5	64	4.8	104	4.5	144	9	184	8	224	4.8	264	4.5	304	6.5
25	5	65	4.5	105	5	145	7.5	185	7.5	225	5	265	4.5	305	8
26	6.5	66	4.5	106	6.4	146	7	186	7.5	226	5	266	4	306	8.3
27	6.5	67	4.5	107	5.5	147	7.5	187	6.5	227	5	267	3.8	307	7
28	6	68	5	108	4.8	148	10.5+	188	5	228	5	268	4	308	7
29	6.5	69	6.5	109	5.5	149	7	189	5	229	5	269	6	309	6.5
30	7	70	7.5	110	7	150	6.5	190	5.5	230	5.5	270	8	310	6
31	7.5	71	9	111	5.5	151	5	191	8	231	7	271	8.5	311	8
32	6	72	7.5	112	5	152	5.5	192	10	232	9	272	9.5	312	9
33	5	73	6	113	4.5	153	8.5	193	8.5	283	7.5	273	8	313	8
34	4.8	74	5	114	4.5	154	8.5	194	7	234	7	274	7	314	5
35	4	75	5	115	4.5	155	8.5	195	6.5	235	6.5	275	7.5		
36	3	76	9.5	116	8.5	156	7.5	196	7	236	6	276	9		
37	5	77	9.8	117	10	157	6	197	7.5	237	6	277	10.5		
38	5.5	78	6.5	118	8.5	158	5.5	198	8	238	5.5	278	9		
39	5	79	5.5	119	6.5	159	8.5	199	8	239	5	279	7		
40	8	80	5.5	120	6	160	9	200	8.5	240	5.5	280	7		

FOX RIVER.

REPORT OF LIEUTENANT F. A. HINMAN, CORPS OF ENGINEERS.

UNITED STATES ENGINEER OFFICE,
Milwaukee, Wis., July 1, 1878.

SIR: In accordance with your instructions of May 27 last, I have the honor to submit the following report of operations on my section of the Fox River improvement for the fiscal year ending June 30, 1878:

By your order of July 30, 1877, my charge over the said work was extended from the mouth of Mechan River to Princeton, Wis., and by your order of November 1, 1877, "the work of construction being completed at Princeton lock site," my charge was defined to be over the works from Portage, Wis., to Lake Apuckaway, including the canal at Portage, and "in view of the contemplated resumption of operations on the Wisconsin River," I was relieved by your order of to-day of the charge of that portion of the Fox River below the head of Lake Buffalo.

1.—GUARD-LOCK.

A coffer-dam was built across the head bay and the upper miter-sill was repaired and bolted down. The upper gates were replanked and new balance-beams put on same. After making these repairs the dam was removed. Minor repairs were also made to the lower gates.

The sand bar which had re-formed in the upper approach was removed (for the second time during the season) with a scow and shovels and cast into the Wisconsin River, so as to admit boats into the lock and canal drawing 2.4 feet, the depth of water on the miter-sills during the lowest stage of water in the Wisconsin River, which occurred in August; the elevation of the surface of the water in the river at Portage was then eight-tenths of a foot below low water of 1872.

This bar formed again this year and was removed in June by dredge No. 1; approximate estimate of amount dredged, 1,121 cubic yards.

A hand-dredge is used here at times to keep the gates free.

It is probable that the causes that have heretofore produced the deposit here will continue, and also that repeated dredging alone must be resorted to in order to keep the channel open.

It is thought that the new guard-lock as proposed would avert this trouble in a great measure.

The channel in the Wisconsin River is now on the opposite side and should be diverted over toward the lock. This can be done by building two short dams above the lock—one nearly abreast of it from the other shore, the other opposite this one just above the point.

No material change is noted in the bank of the river adjacent to this lock.

2.—PORTAGE CANAL.

The docking on the north side of the canal adjoining Wisconsin street was extended 70 feet, and a sidewalk and railing built along the said extension.

Hon. R. L. D. Potter, while special assistant attorney-general for this work, gave opinions to the effect that the general government was under no obligations to construct or maintain any bridge at Montello or across this canal at Wisconsin street.

The Mayor of Portage, Wis., was notified by your letter of March 26 last that the general government would abide by Mr. Potter's opinions, and at the Mayor's request copies of the said opinions were sent to him April 18 last.

The bridge at Wisconsin street should be repaired at once, and in due time a new bridge should be built squarely across the canal, so as to afford a clear water-way of 50 feet.

The 23d of May last a freight engine and car belonging to the Chicago, Milwaukee and Saint Paul Railroad Company ran into the canal at Ketchum's Point, the draw being open at the time. Navigation was somewhat obstructed but not closed by this accident; however, it was thought best to draw down the level to assist in removing the wreck. This was quickly done and the canal carefully examined and found to be in good condition, except that the top timber of the revetment had been crowded in a little here and there.

It so happened that navigation did not suffer by draining the canal.

In June dredge No. 1 removed about 390 cubic yards of material that had drained into the canal from the streets of Portage.

The repairs to the docking along Mr. Bohag's property at Wisconsin street were made at small expense.

3.—WINNEBAGO LOCK.

Minor repairs were made to this lock.

4.—GOVERNOR'S BEND LOCK AND DAM.

Minor repairs were made to these works. The gates were kept closed during the winter to prevent a rapid re-forming of the bar at Winnebago lock above. No bad esults followed except that the bar increased a little, which must be expected every year.

5.—MONTELLO LOCK.

Minor repairs were made to this lock.

6.—MONTELLO DAM.

Minor repairs were made to the embankment at each end of the dam; the backing was also repaired near the north end.

7.—MONTELLO LEVEE.

This levee at the foot of Buffalo Lake is about 2,200 linear feet in length; 1,800 feet of this had been damaged, principally by the muskrats that inhabit it, and also by the influence of the westerly winds that have swept over the lake this season. This was repaired by backing it with material dredged from the lake and by facing 1,447 inear feet on the lake side between high and low water marks with broken stone. The balance of the levee is protected by a marsh. The levee is 28 feet wide at the ow-water mark, and 10 feet wide at the top, which is 5 feet above low-water mark. It should be sown to grass-seed at the proper time; fences have been put across it at either end to protect it from cattle, teams, &c.

8.—GRAND RIVER LOCK.

The excavations were made for tight timber wing-walls at each approach. These walls were framed, constructed, and filled with stone and clay puddle. The embankments behind the lock-walls were completed; the miter-sills were framed and placed; the hangings for the gates were made, and the gates (already framed) were hung; four capstans were made and placed for operating the gates; the horizontal platform was planked and calked; six valves were made, and all the valves were put in.

Shores of 12-inch by 12-inch timber were put under the platform which supports the upper miter-sill; the tail-bay was paved with stone from the lower end of the lock-loor to a point 40 feet distant, to prevent scouring. Six snubbing-posts were erected; no fender-piles were required.

The lock was completed August 21, except the coping, which was put on the following June. A fence was constructed to inclose the government land around the lock-site.

9.—GRAND RIVER DAM (TEMPORARY).

This dam was completed August 25. It is similar to the Wisconsin River dams, forming a long rapid. The dam is 105 feet long; each shore-protection extends 50 feet above and the same distance below the dam, making 200 feet of shore-protection. There are 266 mats, each 20 feet long, and 30 cords of stone in the dam.

10.—PRINCETON LOCK.

Work was resumed on the construction of this lock August 24. The excavations for the slope-walls were made, and the latter constructed of stone. The wing-walls already commenced were completed; the embankments were completed behind all the walls; the hangings for the gates were completed, and capstans for operating the same were made and placed; valves were put in position; the gates already framed and partially put together were hung; 6 snubbing-posts were put up and fender-piles driven along the approaches to the lock; a cluster of piles was driven above the lock at the angle made by the river and canal. The lock, except the coping, was completed the latter part of October.

A fence was built to inclose the government land around the lock-site.

11.—PRINCETON DAM (TEMPORARY).

This dam consists of 61 piles, 16 inches in diameter at the butt, driven 2¼ feet apart from center to center, in a line perpendicular to the banks, and through an apron of one course each of brush-mats and stone. A 12-inch by 12-inch timber-crest is botled to the upstream sides of these piles, and brush-mats in continuous courses held down by stone abut against the upstream side of the line of piles. A course of face-mats protects the upstream ends of these mats. The dam was completed the latter pa of October, except the backing, which was not finished for want of time.

The length of the dam is 191 feet. The usual Wisconsin River shore-protection wa built at each end. The length of the north shore-protection is 113 feet; of the south sho- protection 119 feet. A dike 229 feet long, of brush and stone, was constructed fro the south shore-protection across the marsh to the high ground.

The slough running around the lock on the north side was closed by a dike of ear brush, and stone 105 feet long. The low portion of the road, 377 feet in length on th north side of the lock across the marsh to the high ground, was raised by a cours brush-mats covered with sand and stone.

12.—DREDGING.

"Clamshell" dredge, No. 4, is well adapted to this work, especially in deep cuts o account of her ability to dispose of material, having a light dipper, a long and he boom, and powerful machinery. Break-downs were rare, scarcely a week having be lost during the entire season. She will last for several years after being repaired. S excavated about 41,842 cubic yards of material, being an hourly average of 50 cu yards, at a cost of 3.93 cents per cubic yard, counting only the usual running e penses. She removed one small bar in the first bend above Grand River lock, five ba between this lock and Lake Apuckaway, and two bars 1,105 feet long just above Princeton Lock, besides constructing Grand River and Princeton canals.

13.—GRAND RIVER CANAL.

The cut for the upper approach to Grand River Lock is 544 feet long; that for th lower approach is 1,252 feet in length, inclusive of 552 feet dredged through a slough. The following are the dimensions of the canal: Length, 1,796 feet; width, 50 fee depth, 5 feet. The canal was completed the first part of August.

14.—PRINCETON CANAL.

This canal adjoining Princeton lock was constructed; the length of the lower c is 698 feet, and of the upper cut 768 feet. Most of the lower cut was through a slough. The depth of the canal is 5 feet, the least width is 60 feet, and the total length is 1,4 feet. It was completed the latter part of October.

15.—MISCELLANEOUS.

For the completion of the iron-work about the locks considerable blacksmithing wa done on the spot. To facilitate operations a quarter-boat was used to accommoda the employés at Grand River and Princeton locks. On the completion of operatio for the season all the boats were taken to Portage for the winter. Dredge No. 4 an three scows were hauled out for repairs, which will be completed this month. Dredg No. 4 has received a new dipper; her old dipper and dipper-frame have also been c down to better adapt them to the work. The old dipper belonging to the steam exc vator will be repaired, so that there will be three good clamshell dippers interchangeable between the steam excavator and dredge No. 4. Dredge No. 1 is receiving a ne crane now, and also a few minor repairs.

A practicable channel of 3 feet existed throughout the whole extent of this portio of the river the last of October. (Dredge No. 4 drew that much when towed up.) I also found a strong 3-feet channel there the 6th ultimo. Navigation closed Novemb 30; it partially opened again in December, and remained open until some time in January. The steamer Montello passed through Montello lock January 9.

The above work was done by hired labor, the materials being purchased in ope market; about one-third the cost of it was for materials and the balance (two-third for labor.

The steam-scow Boscobel is well adapted to tending dredges and construction-parties on the river.

A hull should be built for the steam excavator in due time.

Parties at Portage run a boat, the Gussy Girdon, regularly between Portage an Berlin. There are other boats that make irregular trips over portions of this sectio of the river. The traffic is not large; it consists principally of merchandise, coal, lumber, and grain.

I have been greatly assisted by Mr. Ed. C. Hinman in the prosecution of the abov work.

16.—GENERAL STATEMENT OF WORK REQUIRED TO COMPLETE THE ABOVE SECTION O THE FOX RIVER.

A new guard-lock should be constructed of masonry at Portage as soon as possibl A new masonry lock should be built at Governor's Bend as soon as practicable; th present lock will need repairs soon; Montello lock will soon require new gates, ga hangings, and coping; a permanent dam should be built in due time at Grand Rive the dam at Governor's Bend will require new abutments shortly; the canal at Portag should be enlarged near the guard-lock to afford a basin for boats to turn around in; houses for lock-tenders are required at Grand River, Governor's Bend, and Fort Winnebago; an immense amount of dredging will be required to deepen, widen, and shorten the channel; the dredging is principally at the upper ends of all the levels; it should be commenced at Winnebago Lock and proceed down the river deepening the present channel first of all wherever it is to remain permanently. Several sand banks can be avoided by making "cut-offs"; the few then remaining will require some protection.

The above work can all be done without closing navigation.

Very respectfully, your obedient servant,

F. A. Hinman,
First Lieutenant, Corps of Engineers.

Maj. D. C. Houston,
Corps of Engineers, U. S. A.

REPORT OF MR. JOHN PIERPONT, ASSISTANT ENGINEER.

United States Engineer Office,
Milwaukee, Wis., July 1, 1878.

Sir: I have the honor to submit the following report of operations on the improvement of that portion of the Fox River, Wisconsin, which has been in my charge during the fiscal year ending June 30, 1878.

1.—PERMANENT DAM AT EUREKA.

At the beginning of the fiscal year the brush dam was backed up with earth and repaired, causing a head of about 20 inches at the lock. There was no head just previous owing to the bad condition in which the spring freshet and ice had left the unbacked dam.

The excavation for the new dam (permanent) was commenced at the same time. The dam was built in the hard land between the canal and river, and was all finished by October 1, 1877.

The structure consists of a pile and timber foundation 25 feet wide and 223 feet long. The bearing piles are driven in 4 rows, 8 feet between piles, the piles in one row being opposite the intervals in the next. These are capped by 12-inch by 12-inch timbers transversal to the stream, and on them are placed the stream sills of 6-inch by 12-inch timber, set on edge 4 feet apart. The latter are tightly planked over with 2-inch plank. The entire upper and down stream faces of the foundation are sheet-piled with 3-inch by 6-inch scantling. At the south end is a masonry abutment 7 feet wide, then a frame dam 150 feet long extending to a masonry center pier 8 feet wide. The foundation of this pier is composed of close piling of 12-inch by 12-inch timber 10 feet long, making a rectangular crib 8 feet by 25 feet outside. An interval of 50 feet occurs between the center pier and north abutment, which is spanned by a swing truss bridge, having its turn-table on the abutment. The bridge is trussed vertically to sustain its own weight and horizontally to sustain the head of water. Vertically under the upstream side of the bridge is a sill 10 inches high, secured to the foundation and extending from the center pier to the abutment. The top of the sill is 6 feet below the level of low water. At intervals of 2¼ feet, posts of 12-inch by 12-inch timber are placed supported at top by the bridge and at bottom by the sill. The intervals between the posts are filled by gates made of 3-inch oak plank which slide in grooves in the posts. Each gate is 4 feet high, and there are two gates to each interval, which makes the top line of the gates 2 feet above the crest of the frame dam. A wooden track is laid on top of the bridge on which runs a car bearing a small derrick by means of which the gates and posts are hoisted out and run with the car off the bridge to the bank on the north side. The bridge is then swung upstream by a capstan and the navigable pass thus opened.

In April last the water found its way under the foundation of the pass, but the leak was stopped with brush, hay, and stone, and no trouble has since been experienced. After the leak was stopped the navigable pass was opened and found to operate in a very satisfactory manner.

Previous to the opening there was a head of 1.8 feet at the dam, which was reduced to zero when the pass was opened. The lowering of the level above the dam was observed just below Berlin Lock (the next above) where the water fell 0.3 foot, the other gauges on the river remaining unchanged, showing that the influence of this dam extends to the next above. The amount of flowage is nearly inappreciable.

A new channel was made for the river through the point cut off by the canal, and a high, firm bank made across the old channel on top of the brush dam, thus forcing the entire river over the crest of the permanent dam and through the new channel. This latter is 75 feet wide and 900 feet long. It was completed November 1, 1877. The stone used for the masonry came from the quarry at Kaukauna.

The following amounts of materials are in the work:

3,040	linear feet of piles.
62,141	feet, board-measure, pine timber and plank.
1,500	feet, board-measure, oak plank.
12,100	pounds iron (wrought and cast).
285	cubic yards masonry.
41,536	cubic yards excavation.

Of the latter, 10,739 cubic yards were excavated by hand from the pit, and sod removed in advance of the dredges. Dredge No. 1 made the first cut along the north line of the proposed channel, dumping on both sides; 7,677 cubic yards were moved in this way at a cost of 4 cents per yard. The balance of the excavation, 23,130 cubic yards, was done by dredge No. 3, the sluice-scow floating in the cut already made, so that all the excavated material was deposited on the north side of the channel. The cost of excavating the material by No. 3 and washing through the sluice to the north bank was 4.7 cents per cubic yard.

2.—BERLIN LOCK, DAM AND CANAL.

This work remained as left in November, 1876, until the first part of August, 1877, when the lock was pumped out and the wing and slope walls built of stone brought from Kaukauna. The gates which had been framed at Kaukauna were set up and hung, valves and miter-sills placed, and all the details adjusted. The excavation of the canal by dredge No. 3 was going on simultaneously, upon the completion of which a dam was built across the river and the lock opened to navigation on September 2, 1877. The dam consists of two rows of piles 12 feet apart, with the piles in each row 6 feet from center to center. The space between the two rows of piles was filled with alternate layers of loose brush and stone, the latter obtained from a quarry near Berlin. A piece of 10-inch by 12-inch timber was bolted to the upstream row of piles to serve as a crest, and the whole dam well backed up with earth by the dredges, producing a head of about 18 inches.

The canal is 2,400 feet long, 50 feet wide, and 5 feet deep; 39,518 cubic yards were excavated by dredge No. 3 at a cost of 3 cents per yard.

The 19-inch coping-stone quarried at Kaukauna was boated to the lock in the fall of 1877, cut during the winter, and laid in June, 1878, so that at this date (excepting a permanent dam) all work at this point has been completed.

3.—WHITE RIVER LOCK, DAM AND CANAL.

This work remained as at the close of the last fiscal year until August 16, 1877, when a force was engaged excavating the canal by hand. The lock was pumped out September 1, and the gates, which were left unhung and had floated out of position during the spring freshet, were replaced and hung; the lower wing-walls raised to the height of the lock-walls; capstans for working the gates placed; the canal excavated, and the lock ready for use on October 20, 1877. The cutting for the canal was so deep the upper part had to be excavated by hand; 15,750 cubic yards were removed in this manner, and the remainder, 6,421 cubic yards, was removed by dredge No. 1 at a cost of 3.54 cents per yard. The canal is 1,150 feet long, 50 feet wide, and 5 feet deep.

During these operations brush and stone were collected for the temporary dam, which was built similarly to that at Berlin, and was completed November 6, 1877. Bowlders bought of neighboring farmers were used in its construction. During the high water of March, 1878, a slight settlement took place at the north end of the dam, which was repaired in May. The 19-inch coping-stone, which had been left at Berlin Lock in the fall of 1877, was cut during the winter and spring and laid last May. A permanent dam is all that is now needed to complete the work at this point.

4.—PRINCETON LOCK, DAM AND CANAL.

At the beginning of the fiscal year part of the stone for the wing-walls had been quarried and hauled to Princeton village, and the remainder purchased of parties in the village, when the work was turned over to Lieut. F. A. Hinman, Corps of Engineers, in accordance with instructions dated July 30, 1877. Under orders dated November 1, 1877, the work was received back with the lock (except coping), brush-dam, and canal completed. A settlement which occurred at the south end of the dam during the spring freshet was repaired last April.

The 19-inch coping-stone brought from Kaukauna to Berlin last fall was cut in April and May and laid in June, 1878, thus completing the lock. A permanent dam is the only additional work needed at this point.

5.—DREDGING IN THE RIVER.

Dredge No. 1, which had been employed on the Lower Fox River during the first part of the year, arrived at Eureka August 8, 1877, and started up the river September 1. Stopping *en route* to assist in backing the temporary dam at Berlin, work was commenced on bars between the mouth of White River and White River Lock on September 8.

A channel was made through four bars 5 feet deep, 30 feet wide, and having an aggregate length of about 1,500 feet. There were 7,030 cubic yards of material removed from these bars, at a cost of 3.4 cents per cubic yard. This work was completed on October 1. The dredge worked on the White River Canal until October 20, when it went to Little Willow Bend and made a short cut-off to straighten the river. The dredge worked until November 3, excavating 4,508 cubic yards at a cost of 3.3 cents per yard. A small bar that had formed just below Eureka Lock from material deposited in the river from the excavation of the pit for the permanent dam was removed by dredge No. 3 from September 12 to 15, 1877. Twenty-two hundred and five cubic yards were excavated at a cost of 3.7 cents per cubic yard.

Very respectfully, your obedient servant,

JOHN PIERPONT,
Assistant Engineer.

Maj. D. C. HOUSTON,
Corps of Engineers, U. S. A.

REPORT OF MR. C. A. FULLER, ASSISTANT ENGINEER.

APPLETON, WIS., *July* 1, 1878.

SIR: I have the honor to submit the following report of operations on the improvement of the Lower Fox River for the fiscal year ending June 30, 1878.

During the year no new works were commenced, operations being restricted to the completion of the locks and dams, which had been, in most cases, nearly finished prior to July 1, 1877, and to thoroughly repairing the old crib-locks, all of which were in bad condition.

Materials for repairs to locks having been purchased and delivered during the winter of 1878, work was commenced on the 19th of February, and pushed as rapidly as possible, that navigation could be resumed at an early date in the spring. Water was let into the canals on the 15th of April, and navigation has uninterruptedly continued since that date. Boats drawing 4¼ feet water have passed, without detention, over the entire route between Oshkosh and Green Bay.

The following outline of operations at each point in the Lower Fox River is respectfully submitted:

1.—APPLETON, FIRST LOCK (OLD).

New lower gates were constructed and hung, and new diamond-blocks made, placed and secured.

2.—APPLETON, SECOND LOCK (NEW).

The coping for the lock-walls, 19 inches in height, was dressed, taken to lock-site, and laid in cement mortar. The riprap wings below the lock were relaid for a distance of 60 feet, and timber-cribs, 50 feet each in length, were framed, bolted, placed thereon, and filled with stone. Additional filling was placed in rear of walls. New top-arms were framed and secured in the four gates; new anchors for gate-hangings placed in wall; permanent gate-hangings and maneuvering apparatus were attached to the gates and the gates rehung. New capstan-platforms were built and the capstans re-set. This lock is completed with exception of doweling and pointing the coping, and constructing steps at the lower end of the south wall.

3.—APPLETON, THIRD LOCK (OLD).

Three new diamond-blocks were made, placed and secured, and a new set of hangings attached to the south wall.

4.—APPLETON, FOURTH LOCK (OLD).

Four new gates were constructed and hung. A large accumulation of sawdust and other *débris* was removed from the space between the breast-wall and the upper gates, and from the lock-chamber.

5.—CEDARS LOCK (OLD).

Two new upper gates were constructed and hung and the upper wing-walls repaired.

6.—LITTLE CHUTE, FIRST LOCK (OLD).

Portions of the plank and timber on both sides were removed and replaced by new.

7.—LITTLE CHUTE, SECOND LOCK (OLD).

Excavations were made in the bottom of the canal above the breast-wall and the rock laid bare, to discover the causes of leaks through the north wing-wall; the seams and holes in the rock bottom were filled with cement, thereby stopping the leaks. The upper wing-walls were repaired; a small portion of plank was removed from the north chamber-wall, and replaced by new; one lower gate was repaired, and one new lower gate constructed and hung.

8.—LITTLE CHUTE COMBINED LOCK (NEW).

Thirteen stone steps were relaid. The setting of coping was finished. Capstan platforms were rebuilt and capstans reset. These locks are completed with exception of pointing and doweling the coping.

9.—KAUKAUNA, FIRST LOCK (OLD).

Four new gates were constructed and hung; 4 new hollow quoins and 2 new miter-sills were constructed, placed and bolted. The recess-walls and old stone walls in rear of hollow quoins were rebuilt. The chamber-walls were partially replanked, and posts and stringers renewed. The upper and lower wing-walls and the capstan platforms were repaired.

10.—KAUKAUNA, SECOND LOCK (OLD).

Four new gates were constructed and hung; 4 new hollow quoins were made, placed and bolted; 2 new miter-sills were framed, placed in position and securely bolted to the rock bottom. The recess-walls and the old stone walls in rear of the hollow quoins were rebuilt. The chamber walls were partially replanked and the posts and stringers renewed; capstan platforms were repaired and the capstans reset.

11.—KAUKAUNA, THIRD LOCK (NEW).

The coping for the lock-walls and for the breast-wall was dressed and laid in cement mortar. Two sets of stone steps were dressed and laid and the lower ends of main walls finished. The upper and lower wing-walls were completed; the filling in rear of main and wing-walls finished. New top-arms were framed and placed in the four gates, new diamond-blocks made and placed, and the gates rehung. New capstan platforms were built and the capstans reset. The construction of this lock is completed with exception of pointing and doweling the coping.

The principal items applied to the construction of this lock during the year are as follows:

1,944 cubic yards of earth embankment.
504 linear feet of stone coping.
14 cubic yards of stone masonry in main walls.
152 cubic yards of masonry in wing-walls.

12.—KAUKAUNA, FOURTH LOCK (NEW).

The coping for the lock-walls and for the breast-wall was dressed and laid in cement mortar. Two sets of stone steps were dressed and laid and the lower ends of main walls finished. The upper and lower wing-walls were finished and the filling in rear of main walls completed. New top-arms were framed and placed in the four gates, new diamond-blocks were made and placed, and the gates rehung. The capstans were reset and new capstan-platforms built. The construction of this lock is completed with exception of pointing and doweling the coping.

The principal items applied to the construction of this lock during the year are as follows:

4,806 cubic yards of earth embankment.
504 linear feet of stone coping.
17.5 cubic yards of stone masonry in main walls.
180 cubic yards of stone masonry in wing-walls.

13.—KAUKAUNA, FIFTH LOCK (OLD).

Two coffer-dams were constructed and the lock pumped out and cleaned. Four new hollow quoins were made, placed, and secured. One new miter-sill was framed, placed and bolted to bottom rock. The upper miter-sill was rebolted. Two new gates, one upper and one lower, were constructed and hung. The four recess-walls were rebuilt and the chamber-walls thoroughly repaired. The upper wing-walls and breast-wall were built up, and the waste-weir near the lock rebuilt.

14.—RAPID CROCHE LOCK (OLD).

The stone steps at the lower end of this lock were reset and laid in cement mortar and the lock-walls repointed with Portland cement.

15.—LITTLE KAUKAUNA DAM (OLD).

One new diamond-block was placed and secured, and two new lower gates were constructed and hung. A portion of the chamber-walls were replanked; new threads were cut on several of the tie-bolts, and new nuts put on.

16.—APPLETON STONE DAM (NEW).

Flush boards were put on, and the rock-bed immediately below the dam examined its entire length without discovering any change in its condition since the completion of the work. The coping-stones for a distance of 160 feet from the west end of the dam were secured by 50 dowels of 1¼-inch round iron, extending into the second course of stone below the coping. The coping-joints were raked out and repointed with Portland cement. The coping of this dam is now doweled throughout its entire length.

17.—CEDARS DAM (NEW).

Seven thousand four hundred and ninety-six cubic yards of clay and gravel backing, with a top dressing of stone spawls, were placed above this dam. A dry-stone retaining wall was built from the north abutment of the dam to the head of the canal, and the old canal walls were raised by constructing 166 cubic yards of dry-stone wall. This work is completed.

18.—LITTLE CHUTE DAM (NEW).

Twelve thousand eight hundred and sixty-nine cubic yards of clay and gravel backing were placed above this dam, completing its construction.

19.—KAUKAUNA DAM (NEW).

Cribs were constructed, placed, and sunk in position, and the gap in the dam, 75 feet in length, was closed. Cribs were framed and placed on the lower side of the dam between the gap and the abutments, and stringers and posts to support the apron were framed and secured in place. An apron of plank 4 inches in thickness, extending the whole length of the dam, was built and the space underneath filled solidly with rubble stone. A stone abutment at the north end of the dam was constructed, and the canal-bank in rear of same puddled. The south abutment was finished, the embankment at both abutments completed, and dry-stone and slope walls laid to protect the banks above the abutments. The sheathing of the upper side of the dam was finished, and the clay and gravel backing placed, completing the construction of this work.

The principal items applied to the construction of this work during the year are as follows:

137.1 cubic yards of cement masonry.
155.7 cubic yards of dry masonry.
300 cubic yards of puddling.
1,952 cubic yards of earth embankment.
6,906 cubic yards of clay and gravel backing.
288.5 cords of rubble-stone filling.
67,536 feet, board measure, of pine lumber.
49,547 feet, board measure, of pine plank.
5,916 pounds of iron drift-bolts.
4,412 pounds of iron spikes.
126 pounds of nails.

20.—RAPID CROCHE DAM (NEW).

The stone for coping the abutments was dressed and laid in cement mortar; 4,992 cubic yards of clay and gravel backing and three scow-loads of stone spawls were placed above the dam, completing the work.

21.—LITTLE KAUKAUNA DAM (NEW).

The stone for coping the abutments was dressed and laid in cement mortar; 56 cords of stone riprap were placed below, and 2,976 cubic yards of clay and gravel backing above the dam. The dry-stone mats below the abutments were raised to full height, and the embankment carried up to the level of the top of the coping. This work is ompleted.

22.—DREDGING.

During the short period that dredge No. 1 operated in the Lower Fox she removed a stone pile from the Menasha channel; dredged the channel of the river above the Appleton stone dam and between Appleton third and fourth locks; removed obstrucions from channel below the Little Chute combined locks; removed the earth filling of coffer-dam in canal near the north abutment of the Kaukauna dam and at Kaukauna irst and fifth locks, and at two different times removed a large quantity of sawdust rom Appleton fourth lock.

23.—QUARRYING.

Two hundred and fifty-five and $\frac{14}{100}$ cords of stone were taken from the Kaukauna quarry prior to September 14, 1877, at which date the work was suspended and the tools, engine, and pump removed and stored. No quarrying has been done since that date.

24.—MISCELLANEOUS.

The steamer Neenah, dredge No. 1, steam-launch, and five flat scows have been calked and otherwise repaired. Repairs have been made at different points along the canal banks wherever required.

A survey has been made of the De Pere dam, and plans and estimates prepared for the construction of a new dam at that point.

All of the old locks, excepting the one at Rapid Croche, will have to be replaced by new ones. They are now in good working order, but need repairs from time to time. When replaced I would respectfully suggest that the new ones be built in the following order: Little Chute, first lock; Little Chute, second; Menasha; Appleton, fourth: Appleton, first; Appleton, third; Cedars; Kaukauna, first; Kaukauna, second; Kaukauna, third; Little Kaukauna, and De Pere.

The lower dam at Appleton and the De Pere dam need not be rebuilt.

The crib pier extending from the Appleton stone dam to the first lock is in bad condition and requires repairs. A retaining-wall of stone should be built against the river side of the pier at an early date.

Very respectfully, your obedient servant,

C. A. FULLER,
Assistant Engineer.

Maj. D. C. HOUSTON,
Corps of Engineers, U. S. A.

APPENDIX B B.

ANNUAL REPORT OF CAPTAIN G. J. LYDECKER, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1878.

UNITED STATES ENGINEER OFFICE,
Chicago, Ill., July 13, 1878.

GENERAL: I have the honor to transmit herewith annual reports of operations for the fiscal year ending June 30, 1878, for works in my charge.

Very respectfully, your obedient servant,

G. J. LYDECKER,
Captain of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

B B 1.

IMPROVEMENT OF THE HARBOR OF CHICAGO, ILLINOIS.

The small amount available ($2,669.48) for this harbor, at the close of the last fiscal year, has restricted operations to slight repairs of existing works such as replacing broken or rotten timbers and plank, and refilling cribs with stone where it had settled or washed out to an extent endangering their stability. The amount was not by any means sufficient for making *all* the necessary repairs, a fact made evident when it is considered that they extended over 5,500 linear feet of exposed crib-work, built at different times during the last ten years, while about 1,000 linear feet of interior work, built between 1840 and 1865, is very badly rotted above the water-line, and broken out at places, allowing the stone filling to fall out, or sand to wash through and diminish the depth of water in the channel. No repairs whatever were made on any of the interior work, but only on the breakwater, and portions of the north pier, built in 1867. The principal work on the former was in refilling cribs, and repairing damage done by vessels, which, missing the harbor entrance during storms, strike along the breakwater and break out timbers. The principal work on the north pier was rendered imperative by damage sustained during the severe storms which visited this locality during the fall of 1877, tearing off most of the planking, making a breach in the crib-work 4 feet below the water-line and washing out upward of 50 cords of stone.

In no case was any work done that did not appear to be absolutely necessary for the present security of the structures; and to keep expenditures down to a minimum, most of the stone used for refilling was obtained by transfer from the more secure parts, as far as safety permitted.

Only 178 cords were purchased. A like course was followed in using over old plank and odd pieces of timber on hand, the purchase of this class of material being limited to about 6,000 feet, board-measure, and 180 linear feet piles.

All work was done by hired labor, and purchases were made in open market under authority contained in department letter of May 9, 1877. The condition of the harbor at the close of the year was as indicated on the accompanying sketch. The channel between the piers admits a draught of 15 feet at mean low-water. The eastern breakwater of the outer harbor, projected by the Board of Engineers in 1870, is finished.

The act approved June 18, 1878, appropriated $75,000 for continuing the improvement of this harbor, and a project has been submitted for its expenditure as follows: For dredging in outer harbor, $15,000; for breakwater construction, $55,000; for general repairs of existing piers and breakwater, $5,000.

My views with reference to the project for completing the breakwater were submitted last May, together with request that a Board of Engineers be convened to consider the question of changing the present project, the necessity of which has been referred to in previous reports.

The following is a copy of the paper referred to:

The project, adopted by the Board of Engineers in 1870, provided for a construction of an eastern breakwater 4,000 feet long, which is completed. It also provided for the construction of a closing pier, at right angles to the breakwater, extending from its southern extremity to the shore.

The officers who have been in charge of the work since that time have not favored the construction of this south or closing pier. Major Houston notes the probable extension of the harbor beyond the southerly limits as now fixed, in which case "the south pier would interfere with the navigation of vessels in the lake front." (Report Chief of Engineers, 1872, p. 129.) He suggests that the interests of the harbor would be best served by the extension of the eastern breakwater beyond its proposed southern terminus.

Major Gillespie states: "It is believed there is no necessity for the construction of a south pier to inclose the outer basin; indeed, it is questionable if such a construction would not prove a disadvantage." (Report Chief of Engineers, 1876, p. 430.) He gives it as his opinion that extending the breakwater 1,000 feet will meet every necessity at present.

It is my opinion that the south pier should not be built; the necessary protection will be obtained and the good of the harbor better secured by continuing the breakwater construction on the present line, commencing at a point about 1,000 feet south of the present terminus; or, commencing at this point, construct a breakwater in a southwesterly direction, but not extending to the shore. The latter plan could be of much lighter work than the former, of less length for the same extent of protection, and hence its cost would be much less; at the same time it would cost no more than the south pier proposed by the board, give much more harbor room, and not interfere with the subsequent extension of the harbor when necessary.

On the sketch herewith are shown the different projects referred to; a careful consideration of their relative merits inclines me to give preference to the one last mentioned.

Owing to the late date at which the appropriation bill was passed, no decision on the above questions has yet been arrived at and no active measures taken for carrying on this season's work. As soon as decided operations will be commenced, and it is probable that during the ensuing year from 600 to 800 linear feet of completed breakwater will be built, and that sufficient dredging will be done to give a perfectly safe channel through the outer harbor, with a minimum depth of 16 feet.

Chicago Harbor is in the collection-district of Chicago. There is a light-house on the shore end of the north pier, a beacon-light on the lake end of the same, and one at the south end of the breakwater.

The number of vessels entered during the year, 10,160; cleared, 10,162.

Total tonnage of vessels entered and cleared, 7,048,706; amount of revenue collected during the year, $1,535,250.93.

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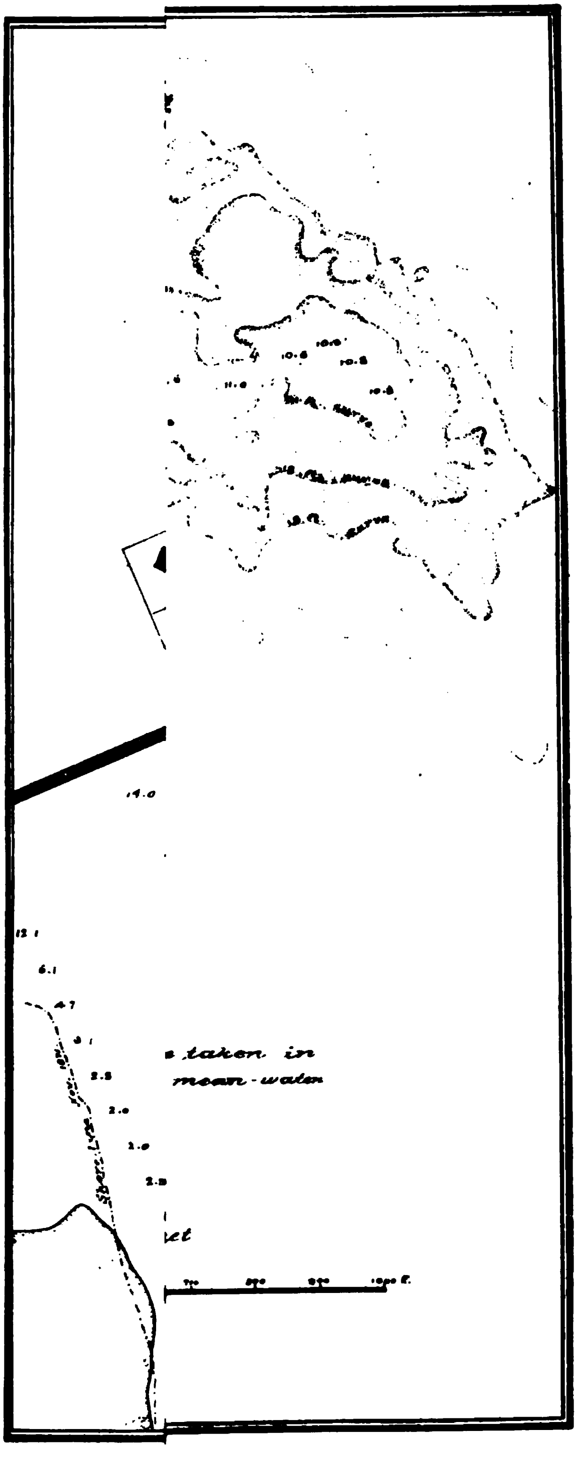
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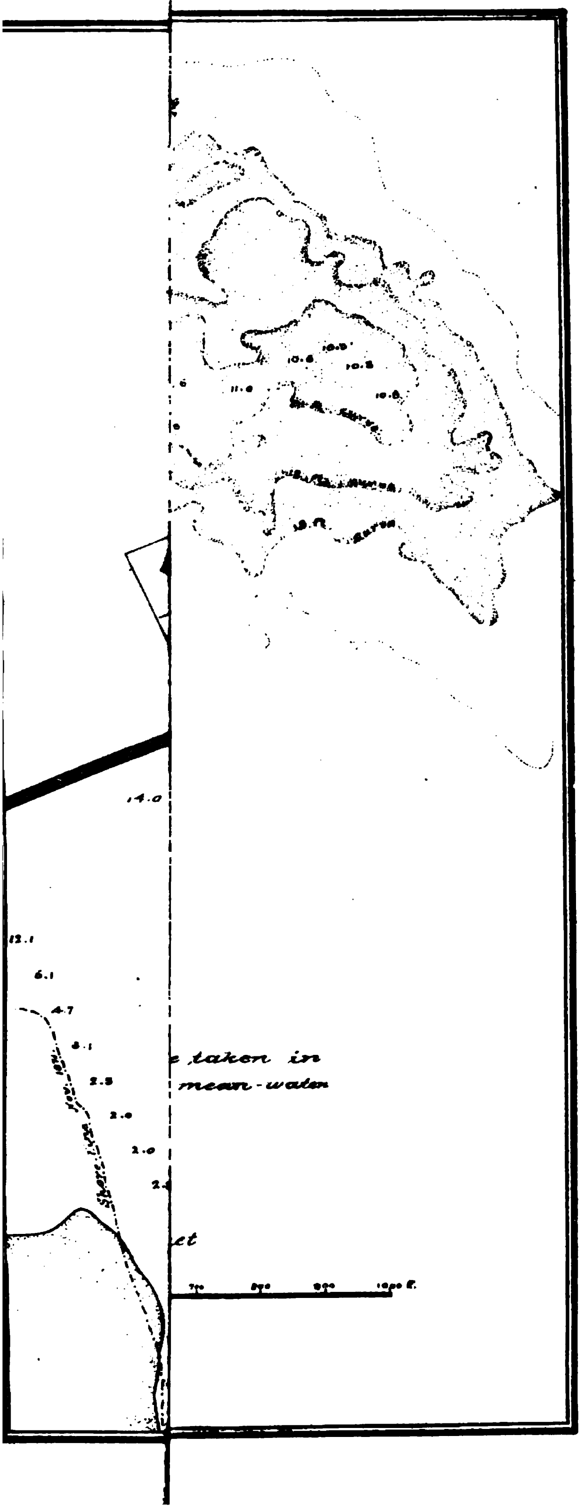
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> tunity for work, we had succeeded in driving only three piles beside crib 5, and connecting them with its superstructure by screw-bolts of 1¼-inch iron, when (November 5) we were overtaken by another terrific gale as strong as any of the season; this was followed by another, fully as severe, on the 9th. Their effect on the work was disastrous in the extreme. The worst damage by the first storm was to cribs 4 and 5, which, from their condition, were least able to withstand any heavy storm. The bolts connecting superstructure of No. 5 with piles were broken off; vertical timbers connecting the superstructure of 4 and 5 with solid work below line of separations described in last month's report were broken, and parts of these cribs above that line driven bodily to the south, through a distance of 3 feet, were only held there by a few timbers of superstructure which extended to the adjacent cribs 3 and 6; and, finally, the tie timbers in the south walls were so badly broken as to place this part of the work beyond repairs. Little damage was done to the other part of the work by this sea directly, but from the strain on crib 6, arising from the connection of its superstructure with that of No. 4, the former had several timbers torn out. To avoid further damage in this manner, the first thing done when the sea subsided sufficiently to admit of work was to saw through the superstructure between cribs 3 and 4 and 5 and 6. We had only succeeded in effecting this when the gale of the 9th struck us, its first act carrying detached parts of cribs 4 and 5 on the beach. The further effects of this gale were to tear away planking and south walls of superstructure of cribs 6, 7, and 8; to tear out or break most of their ties, carry away some planking of cribs 2, 3, 9, and 10, and wash out large quantities of stone. Since then we have secured and repaired, as far as practicable, what is left of the work, a great deal of the stone required for refilling being obtained by dredging. Its condition is now as follows: Crib 1 gone to 5 feet below water-line (it has been in this condition since May 17, 1876); cribs 2, 3, 9, 10, 11, and 12 with superstructure complete to fourth course, well filled with stone and close planked on top; cribs 4 and 5 gone to 4 feet below water-line; cribs 6, 7, and 8 have a partial superstructure (all we were able to save) about 11 feet wide, being over the north (or sea side) compartments of the cribs, against which a backing of heavy stone has been placed for additional security; the balance of the superstructure of these cribs is gone to the water-line. In making the repairs much of the work was done during the nights, the force working by the aid of torches. * * *
>
> In addition to damaging the breakwater, the gales of this season have twice carried away the floating light anchored at the entrance of the harbor to warn vessels away from submerged crib No. 1. * * *

The funds necessary for effecting the repairs above indicated were supplied by a special allotment of $2,500 from the appropriation for "repairs, preservation, extension, and completion of river and harbor works."

From that time on to the close of the fiscal year, more or less damage was done from time to time, and occasional repairs were made when it appeared that anything was to be gained by doing so, and in this way, though most of the work above water is in a badly damaged condition, we have succeeded in holding it together in such a way as to protect the work below water to a great extent.

I am satisfied that the troubles at this place can only be overcome by getting a completed superstructure on the cribs before the season of heavy storms; that the first essential for securing the cribs already in place is to finish the superstructure to the full height, which height, as urged in my last annual report, should not be less than 8 feet; and to guard against like troubles in the future, I would urge the importance of adopting some method of construction which will admit of placing the superstructure as rapidly as the cribs are sunk. Such method calls for arrangements for giving the cribs a level position in the beginning, and for securing them against any subsequent change of position as to either line or level. The only practical method which accomplishes this, so far as I know, is that tried with such good results at Calumet Harbor during the past year, as described in the report for that harbor, viz, the method in which the cribs are sunk on a foundation of bearing piles.

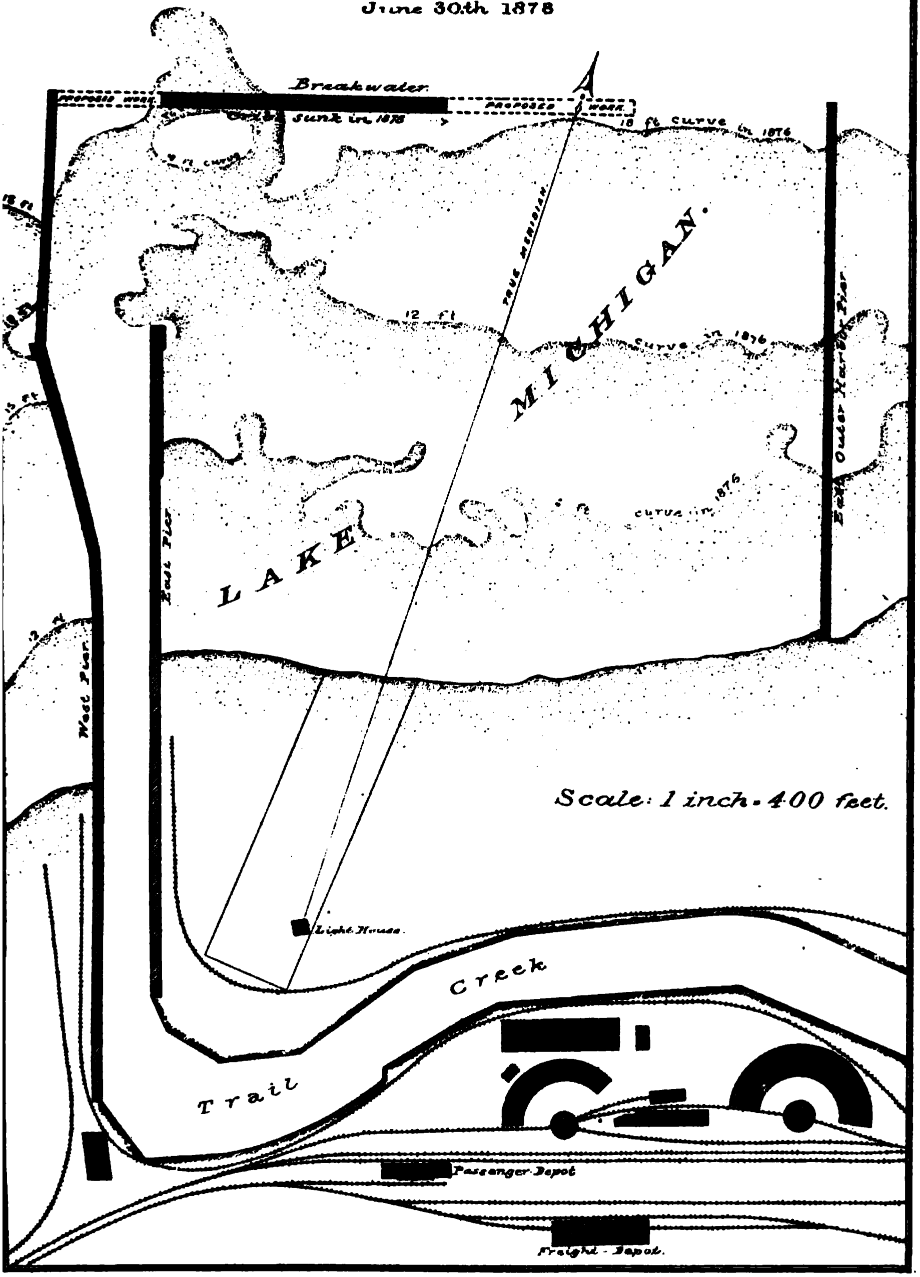
Having carefully considered the difficulties at Michigan City, and sought diligently for the cause, I submitted to the department a memoranda, dated May 4, "bearing on the completion of the outer harbor, and modification of present project." In this was stated my reasons for recom-

SKETCH OF

MICHIGAN CITY HARBOR

INDIANA

June 30th 1878



mending a departure from the method of construction prescribed by the Board of Engineers, and I was directed to call attention to this memoranda when submitting my project for operations for the ensuing year.

Having transferred the charge of this work to Maj. Jared A. Smith, Corps of Engineers, to date from the close of the fiscal year (June 30, 1878), I was not called upon for any project. Accordingly, I have no report to submit as to measures for prosecuting the work during the season.

The original estimate for this harbor was $324,421.40. There has been already appropriated $312,500, this amount including the amount appropriated by act approved June 18, 1878 ($75,000), and $2,500 allotted from the appropriation for "repairs, preservation, extension, and completion of river and harbor works."

It is also to be noted that of the $75,000 last appropriated it is provided that "$25,000 shall be expended for the improvement of the inner harbor." Hence the total appropriated and allotted for the work recommended by the Board of Engineers is $287,500. The amount expended to June 30, 1878, is $239,121.82.

After the breakwater is completed a large amount of dredging will be absolutely necessary in the outer harbor; to accomplish this, finish the breakwater, and put the old piers in secure repairs, an appropriation of at least $50,000 should be made for the year ending June 30, 1880. This amount should all be applied to the completion of the outer harbor, and if so applied will, in my opinion, accomplish the improvement designed by the Board of Engineers at a total cost of $337,500, or about $13,000 in excess of the original estimate. This excess is readily accounted for when we consider the unusual difficulties experienced at this harbor and the successions of disasters detailed in the last two annual reports.

The collector of customs for the district of Chicago, in which the harbor is located, furnishes the following commercial statistics:

Entrances, 421; clearances, 415; tonnage, 114,164. Revenue, stated at about $41.87, is included in the total revenue reported for the port of Chicago.

There is a light-house on the shore near the shore-end of the east pier, and a beacon-light on the lake-end of the west pier.

Money statement.

July 1, 1877, amount available	$8,990 11	
Allotment from appropriation for "repairs, preservation, extension, and completion of river and harbor works"	2,500 00	
Amount appropriated by act approved June 18, 1878	75,000 00	
		$86,490 11
July 1, 1878, amount expended during fiscal year		11,490 11
July 1, 1878, amount available		75,000 00
Amount (estimated) required for completion of existing project		50,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1880		50,000 00

BB 4.

IMPROVEMENT OF THE HARBOR AT NEW BUFFALO, MICHIGAN.

No work has been done during the year. None is contemplated for the ensuing year, and no further appropriation is recommended.

The amount appropriated to date is $70,000, of which $65,000 has been expended. No money has been appropriated since 1872.

There has been no examination of the harbor during the present fiscal year.

New Buffalo is in the collection-district of Grand Haven, Mich. No commercial statistics to report.

There is no light-house at the harbor, the nearest being that at Michigan City, distant 10 miles in a southwesterly direction.

Money statement.

July 1, 1877, amount available	$5,013
July 1, 1878, amount expended during fiscal year	13
July 1, 1878, amount available	5,000

B B 5.

IMPROVEMENT OF ILLINOIS RIVER.

Under orders to relieve Col. J. N. Macomb, Corps of Engineers, I assumed charge of this improvement November 13, 1877.

The principal work in progress from the commencement of the fiscal year up to that time was dredging, the details of which are fully set forth in the following extract from the report of R. A. Brown, assistant engineer, in local charge of the work:

> At the close of the last fiscal year work was progressing at Bath Chute Bar No. 1, at the head of Grand Island, under the contract with Mr. H. S. Brown, Hamilton, Ill., dated June 22, 1877, with an equipment consisting of three Osgood dredges, one towboat, and a full complement of dumping-scows.
>
> On the 18th of July, the new dredge (No. 4) having been purchased by the government, for use in the Des Moines Rapids Canal, was transferred to that work.
>
> The remaining plant, now consisting of two dredges, one towboat, six dump-scows and one flatboat, continued operations in Bath Chute up to the 28th, when it was moved to Devil's Elbow Bar, for the purpose of restoring the channel at that point, the survey of the last month developing an accretion of sand in the improved channel of 1871. This proved to be the most formidable obstruction then existing on the river.
>
> Work was commenced here on the 30th of July and continued up to the 16th of August, completing two cuts of 20 feet width each through the bar, when the equipment was withdrawn from the work, by permission, for the purpose of excavating for the dam foundation at Copperas Creek lock (State work.)
>
> The dredges returning, operations were resumed on the 24th, the suspension being six and one-half working days.
>
> On the 27th the towboat broke one of her main shafts, causing another suspension of four days for repairs.
>
> Thus the number of working days for the dredges during the month of August was reduced to sixteen and one-half.
>
> The mean amount of excavation per dredge was 368 cubic yards per day.
>
> While engaged in this work communications by telegraph and mail from the president of both the Saint Louis and Naples and Saint Louis and Illinois Packet Companies called attention to obstructions at Pearl Shoals, Otwell's and Fisher's Island Bars, in a section of river from 2 to 4 miles below Grand Pass Bridge.
>
> August 30 authority was obtained from your predecessor, Colonel Macomb, by telegraph, to move the fleet whithersoever I deemed best.
>
> On the 1st of September the engineer quarters were moved to Pearl Shoals.
>
> Ascertaining by surveys the necessity of the case, on the 5th I directed the assistant engineer with the dredges, after accomplishing certain work at Devil's Elbow Bar, to move the fleet to Pearl Shoals without delay. Accordingly the dredges suspended work at the former bar on the 7th at 4 p. m., arrived at Pearl Shoals on the 10th at 4.30 p. m., and commenced work the next morning, September 11, at 7 a. m., cutting off a point of bar at a section of work left unfinished in the autumn of 1875.
>
> The estimated time for the removal of this obstruction was about twelve to fifteen days, but the management of the work on the part of the contractor resulted in a protracted delay in its prosecution.
>
> This failure was very much to be regretted, as prompt and energetic movements

such cases result in much good to commercial interests and the public generally. A delay subjects those to whom the work is intrusted to severe and unjust criticism.

After opening a channel 80 feet in width through the bar, leading into an improved channel of 1875, and removing a lump (40 feet by 220 feet) at Otwell's Bar, about one-half mile below, the fleet was moved to Fisher's Island Bar, some 1¼ miles farther down the river, on the 10th of October, and continued work up to the 27th, making four cuts of 20 feet width each through the crest of the bar, leading into 3 feet depth at low-water, when, by permission of the engineer in charge, the work of dredging was suspended, the contractor representing that his plant was needed at Copperas Creek lock to perform certain work he had made an agreement to do before the closing of navigation..

Advantage was taken of the movement of the dredging fleet upriver to have the engineer quarters towed to Beardstown, with a view of making some surveys in that vicinity during the month of November for the purpose of planning future work. Duties incident to the transfer of the work from the care of your predecessor to your charge, together with unfavorable weather, prevented the execution of the plans for the customary field-work at the close of the season, but as a considerable amount of surveying had been done during the months of September and October, the failure to carry out the plans for the above-mentioned work during November proved no detriment to the service.

At the close of November the small boats were stored in warehouse, and general preparations made for winter quarters.

From the time the work came into my charge up to near the middle of last April, nothing but the necessary office-work was in progress. The plotting of field-notes of the summer's work, preparation of record-maps, and others required for the future conduct of the work, kept the reduced engineering party on the quarter-boat steadily and profitably employed.

Active operations were resumed at Fisher's Island Bar on the 13th of April, in continuation of the work in progress at the date of suspension. Good progress was made until May 6, when high water brought everything to a stand-still.` This condition of affairs lasted until June 26, when the dredge resumed, and, after two days' work, finished the final cut necessary for a channel 100 feet wide. To accomplish this, and in view of the long delay occasioned by high water, the contract with Mr. Brown was extended two weeks, viz, from June 15 to June 29. It was then closed and settlement made.

The result of the year's operations has been to give very material improvement for navigation over some of the worst places on the river, while the channels excavated through the various bars have been only partial as to width. They were in each case sufficient to give a practicable channel 4 feet deep. All the work done is within the limits of channels proposed for the completed improvement.

The movement from point to point, doing a little work at each, without completing the channel at any, adds to the expense without doubt. It is also certain that these partial improvements are less permanent than a finished channel with the necessary dams and dikes. Nevertheess, by no other course can the immediate interest of navigation be so well subserved, and I understand that this purpose is one of the objects o be kept in view in arranging for carrying on the work.

After careful consideration of the matter, I have been forced to the onclusion that the speedy and economical completion of this improvement demands a radical change in the method of carrying on the work. As far as the question of dredging and the construction of wing-dams or etties is concerned, I am satisfied that it would be to the best interest of the government in every respect if we owned and operated our machinery nstead of doing the work by contract. The cost for both dredging and dam-building under the latter system is excessive, and many delays are xperienced. The price for dredging, exclusive of engineering and superntendence, varies from 25 cents to 28 cents per cubic yard, whereas xperience at other localities indicates that, with *machinery properly adapted to the work*, the cost should not exceed 15 cents per yard, including superintendence. An equal or greater saving could be made on the construction of brush and stone dams. The appended report of the assistant in charge of the work contains detailed statements of cost of constructing a dam near Bedford, showing the actual cost for *labor* and material to be *less than half that* paid to the contractor under the contract-prices.

Two principal causes combine to make contract-prices high on this work. First, the machinery on the river is *not* adapted to the exceptional character of the work, and the actual cost of doing the work is greater than if machinery of special construction were used. In the second place, the parties owning the plant on the river have practically no opposition, unless they raise the price so high as to induce some distant corporation to bring out new machinery, to do which would be a matter of considerable expense. The result is, the present occupants of the field have matters all their own way, and at the last letting were the only bidders.

Another item of considerable importance is that under the contract system the engineering operations must be in great detail. Very close soundings, careful computations, accurate maps and records, are necessary for exact calculation of amounts due the contractor, and for the protection of the government against subsequent claims.

In consideration of the above facts, I have recommended in my project for the ensuing year that the government apply about $35,000 of the present appropriation to purchasing or building the machinery for doing the work; this machinery to consist of two dredges of special construction to adapt them to the work, four dump-scows arranged for side-dumping, and one towboat.

As some time would elapse before this plant could be made ready for operations, it was proposed to make an open contract for continuing the work until our own machinery becomes available.

I am satisfied that if this system be adopted it will result in a very marked saving, and the work will be pushed forward with much more vigor.

Owing to the lack of funds it has been impracticable to build, during the past two years, the dams and jetties so necessary to the preservation and maintenance of the improved channels. It is submitted that the appropriations for the work should be at least sufficient to build these accessory structures as fast as the channels are dredged, thereby saving the labor required for their restoration. For this purpose, and for continuing dredging operations necessary to the plan of improvement adopted, the appropriation for the fiscal year ending June 30, 1880, should not be less than $75,000, supposing the change in the manner of carrying on the work is adopted. If work be continued under the contract system, as heretofore, this sum should be increased to at least $100,000 for the accomplishment of anything like the same amount of work.

For detailed statement of work done on the river, surveys, commercial statistics, and other matters of interest pertaining to this improvement, I have the honor to refer to additional extracts from the report of R. A. Brown, assistant engineer, appended hereto.

Money statement.

July 1, 1877, amount available	$27,624 14	
Amount appropriated by act approved June 18, 1878	75,000 00	
		$102,624 14
July 1, 1878, amount expended during fiscal year		24,490 72
July 1, 1878, amount available		78,133 42
Amount (estimated) required for completion of existing project		150,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1880.		75,000 00

EXTRACTS FROM REPORT OF MR. R. A. BROWN, ASSISTANT ENGINEER.

NAPLES, ILL., *July* 1, 1878.

CAPTAIN: I have the honor to submit the following report of operations for the improvement of the Illinois River during the fiscal year ending June 30, 1878.

* * * * * * *

MATERIAL RESULTS OF THE YEAR'S WORK.

DREDGING.

A channel has been provided through bar No. 1 at the head of Grand Island, leading into Bath Chute; length 2,468 feet, width 140 feet, and low water depth 4 feet.

A partial channel through bar No. 2, Bath Chute; length 1,200 feet, width 60 feet, and depth 4 feet.

At Devil's Elbow Bar, in the work of restoration, the dimensions of channel opened are as follows (commencing at the head of the bar), viz: 1,400 feet by 80 feet wide, 4 feet deep; 800 feet by 60 feet wide, 4 feet deep; 1,000 feet by 40 feet wide, 4 feet deep; total, 3,200 feet, practically providing a depth of 4 feet.

At Pearl Shoals the dimensions of the improved channel are: 1,600 feet long, 80 feet wide, and 4 feet deep at low water.

At Otwell's Bar a lump has been removed, the dimensions of which are 40 feet wide, 220 feet long, to a depth of 4 feet.

At Fisher's Island Bar a channel has been provided 3,500 feet in length, 100 feet in width, and 4 feet deep, high water causing a suspension, preventing the completion of this work to the desired width.

All the dredging at these points has been done with a view of giving a 4 feet low water depth; also to form a part of the contemplated thorough and complete improvement. In no case has work been done outside the limits of our proposed channel, although the object has been to give relief in the most expeditious manner practicable.

SURVEYS.

During the year the following surveys have been made:

In July, a detailed survey of Devil's Elbow Bar; in August, a preliminary survey of Spoon River Bar; in September and October, a survey of a section of river extending from Pearl Landing to Apple Creek Bar, including Pearl Shoals, Otwell's Bar, Spar Island Bar, Fisher's Island Bar, School-House Bar, and Apple Creek Bar.

The surveys of Pearl Shoals, Otwell's and Fisher's Island Bars were made in detail for the purpose of improving the channels. Those of Spar Island, School-House, and Apple Creek Bars, for the purpose of inspecting the channel improved in 1875. No deterioration is at either place developed.

During the month of April, 1878, a detailed survey of Fisher's Island Bar was made, developing a material scour in the lower section. In the section worked over last October is found an accretion of loose sand. The increased velocity of current produced by the opening of the channel below, and the contraction of transverse section here, should be sufficient to remove this new deposit.

INSPECTION OF LATE IMPROVEMENTS.

During the favorable season of low water in September and October last, a thorough inspection was made of dams and training-walls in the vicinity of Pearl Shoals and Apple Creek. All were found in excellent condition. The accretion caused by them was decidedly satisfactory, and must assist largely in the contraction of the low water channel to the desired limit. This feature of the improvement is truly encouraging.

The prosecution of operations under contract necessitates a large amount of field and office work.

Preliminary surveys are first made to determine the most practicable and economical location of channel. After platting and staking out, detailed surveys follow (in the contemplated channel only) for the purpose of measuring the material in excavation.

After the dredging is completed, a detailed survey of the improved channel is made for inspecting the work and estimating the amount of material excavated.

The positions of soundings are determined by angles at each extremity of a base, are calculated, and platted by co-ordinates.

In prosecuting the work during a high stage of the river, it is frequently desirable to locate on the map the position of the dredges several times during the day in order to prevent any controversy as to whether a certain field has been passed over.

Soundings are also frequently taken as the work progresses to determine any matter of this nature.

PERMANENCE OF THE IMPROVEMENT.

In no case where the system has been carried out literally has accretion taken pla in the improved channel. I am confident that the channel of Devil's Elbow Bar ca be maintained by the construction of two brush and stone dams, properly located a a cost of less than $2,500.

DETRITUS FROM CERTAIN CREEKS

must be expected. Timely and energetic movements in its removal will be assis largely by nature. It is suggested that this be made one of the prominent part the work, and that in no case it be neglected whenever practicable to work.

* * * * * * *

MAINTENANCE.

For the purpose of giving additional width to channels already partially impro and of restoring obstructed channels, I most respectfully renew the recommendatio in former reports concerning the purchase of an equipment to be operated by th department direct.

Experience teaches that promptness and energy, on occasions of this nature, ad largely to the value of this system of improvements.

* * * * * * *

MAPS.

During the suspension of operations under contract, was projected—I. A map o Spoon River Bar, scale 1″=100′, from notes of the preliminary survey of August, 18 II. A map of a section of river extending from Pearl Landing to Apple Creek, sca 1″=200′, from notes of September and October, 1877.

RECORD MAPS.

List of maps for record, scale $\frac{1}{5000}$, showing work done during the years 1869 t 1872, July 31, inclusive, completed and forwarded to your office May 11, 1878, as p invoice, viz:

Sheet I. Peoria bridge and Peoria Flats.
Sheet II. Spring Branch, Crow Creek, and Senachewine Bar.
Sheet III. Tamarch Island; Dutchman's, Kickapoo, and Lick Creek Bars.
Sheet IV. Moore's Island; Toll-Gate, Beardstown, Devil's Elbow, Naples, and El River Bars.

List of maps for record, scale $\frac{1}{9600}$, showing the condition of bars before and aft improvement, work done during the years 1874 to 1876, June 30, inclusive, complet and forwarded May 25, 1878, as per invoice, viz:

Sheet I. Plan of dams and jetties (retained for this report).
Sheet II. Map of Sugar Creek Bar, 1874 and 1875.
Sheet III. Map of McKee's Creek Bar, 1875 and 1876.
Sheet IV. Map of Naples Flats, 1874 and 1875.
Sheet V. Map of Little Blue River Bar, 1875 and 1876.
Sheet VI. Map of Spar Island Bar, 1874 and 1875.
Sheet VII. Map of School-House Bar, 1874 and 1875.
Sheet VIII. Map of Apple Creek Bar, 1874 and 1875.
Sheet IX. Map of French Bar, 1874 and 1875.

Tracings of all the above-mentioned record maps have been made and retained i this office.

With this report are transmitted the following drawings:

Plate I. Plan of brush and stone dam.
Plate II. Map of Bar No. 1, Bath Chute. } Scale $\frac{1}{6000}$.
Plate III. Map of Fisher's Island Bar. }

The maps show the condition of bars before and after improvement.

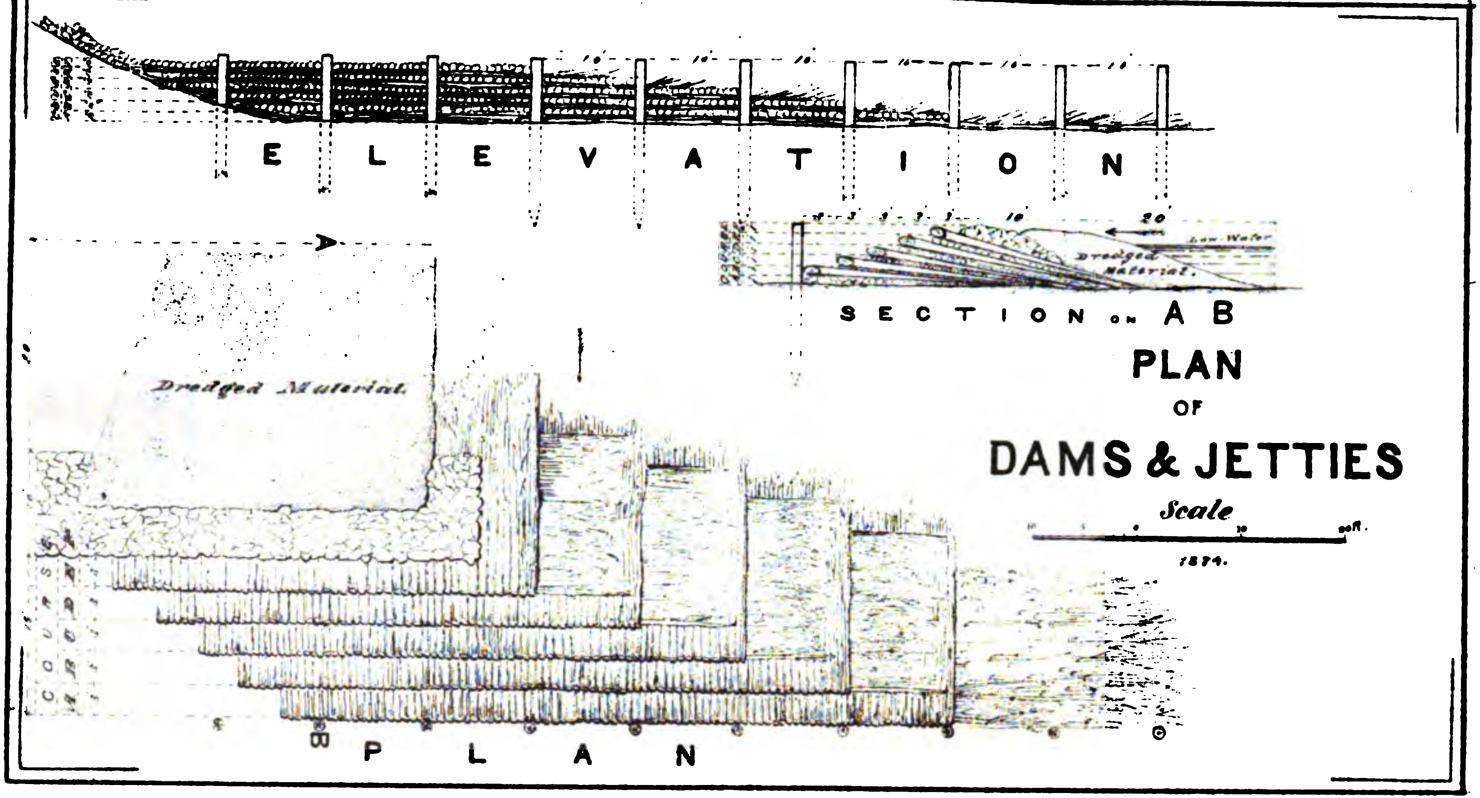
DAMS AND JETTIES.

No work has been done during the past year in the construction of brush and sto dams, the fund not being sufficient to warrant an outlay in that direction.

The material obtained from dredging has been utilized as heretofore, as far as prac cable, in the construction of earth dikes at the following points, viz:

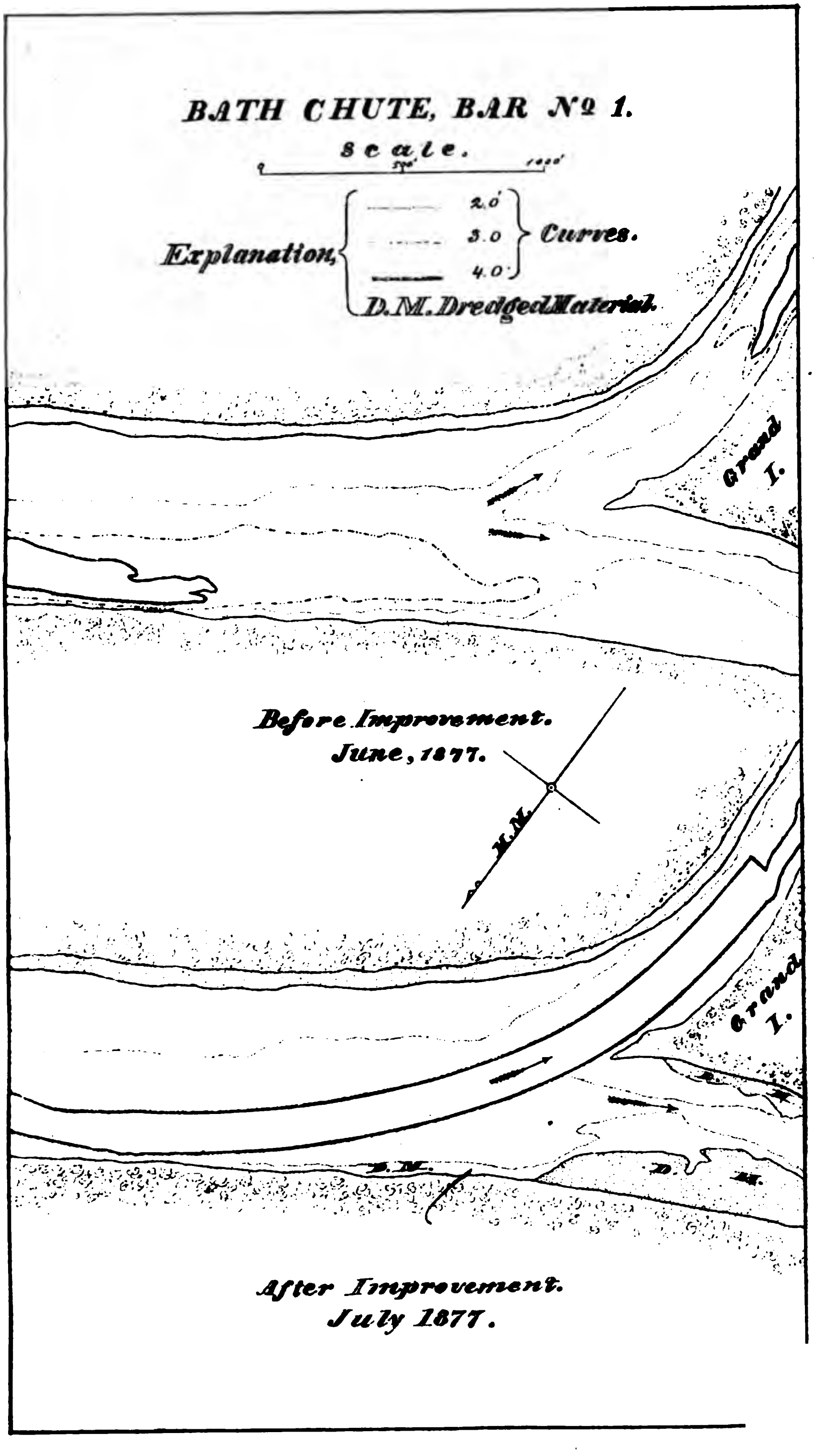
At the head of Grand Island, partially closing West Point Chute, leaving a ga 150 feet in width with the former depth, for the passing of ice or other tows.

Plate 1.



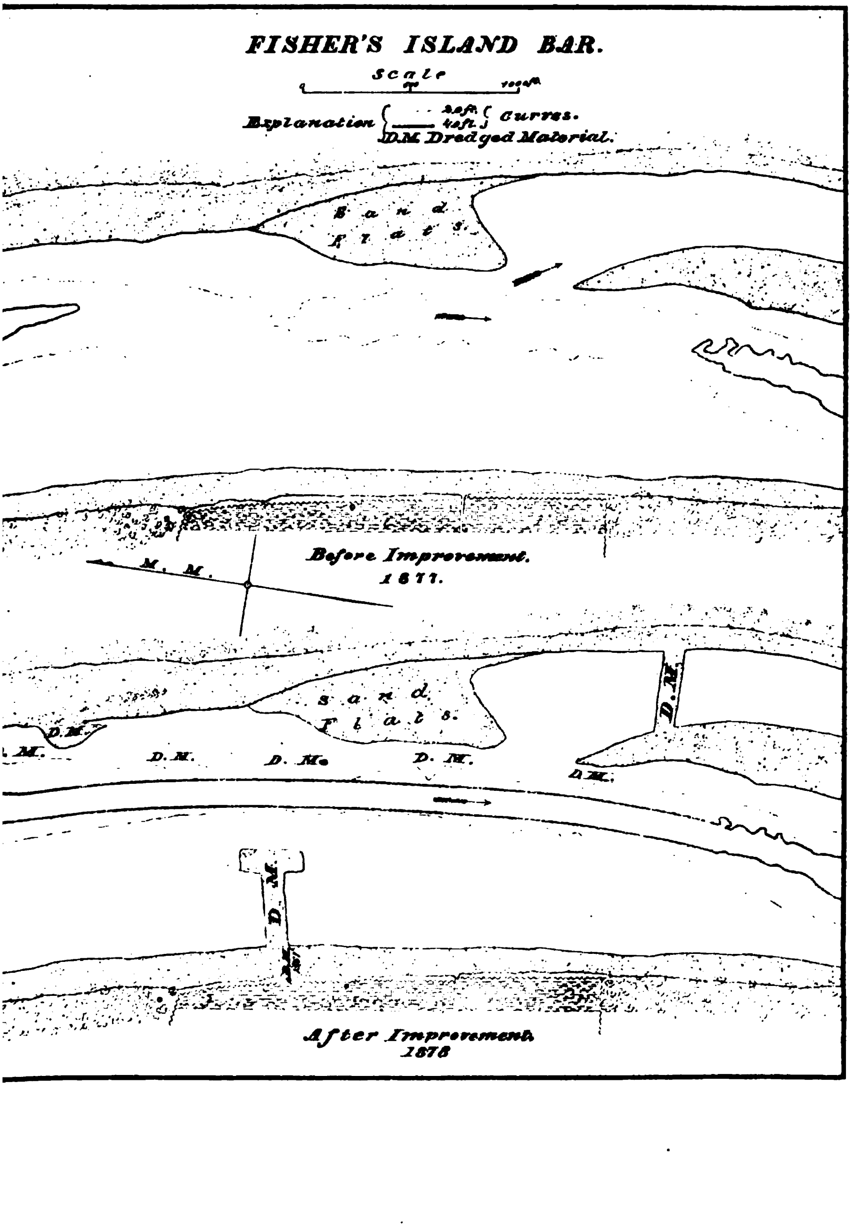
PLAN
OF
DAMS & JETTIES

Plate II.



BATH CHUTE, BAR No 1.

Plate III.



FISHER'S ISLAND BAR.

At Devil's Elbow Bar the excavated material was deposited in rude dikes, extending from the west shore, contracting the transverse section of the river as much as was racticable at that low stage.

At Pearl Shoals and Fisher's Island Bar, during September and October, under the ike disadvantages, the same method was pursued, bringing the dikes to near low ater surface.

During the high stage of the river in April and May was constructed with dredged aterial an earth dike 350 feet in length, closing Fisher's Island Chute; also one proecting from the west shore, about midway of the bar—length 450 feet.

* * * * * * *

tatement of cost of constructing a dam near Bedford, closing Slim Island Chute, November, 1874. *Mean dimensions: Length,* 330 *feet; base,* 39.5 *feet; depth,* 6.5 *feet.*

Items.	Quantities.	Contract price.	Amount.	Total.
iling	945 linear feet	$0 15	$141 75	
rush	288 cords	2 25	648 00	
tone	207 cubic yards.	2 00	414 00	
Total cost to the government				$1, 203 75
		Price.		
Cost of construction to contractor.				
iling	63 sticks		31 00	
rush	1 lot		20 00	
tone	207 cubic yards.	45	93 15	
ngineer and foreman	16 days	2 00	32 00	
aborers	114 days	1 75	199 50	
uperintendent, at $200 per month	20 days	6 66⅔	133 33	
uel and deterioration of implements			66 67	
Total cost to contractor				575 65
Net profit to contractor				628 10

RÉSUMÉ.

	Cubic yards.
mount of brush in dam (288 cords)	1, 365
mount of stone in dam	207
Total amount of material in dam	1, 572

$$\frac{\$1{,}203.75}{1{,}572 \text{ c. yds.}} = 76\tfrac{1}{4} \text{ cents per cubic yard, cost to government.}$$

$$\frac{\$575.65}{1{,}572 \text{ c. yds.}} = 36.6 \text{ cents per cubic yard, cost to contractor.}$$

Table showing the amount of work performed and results obtained for the improvement of the Illinois River during the fiscal year ending June 30, 1878.

Date.		Location.	Amount and cost of work.							Results.						Remarks.
										Dimensions of channel at low-water, in feet.						
										Before improvement (approximate).			After improvement.			
Year.	Month.	Locality.	Cubic yards earth excavation.	Price per cubic yard.	Cost of dredging.	Time of dredging employed by the hour.	Price per hour.	Cost of time-work.	Total cost of work.	Length.	Width.	Depth.	Length.	Width.	Depth.	
						h. m.										
1877..	July..............	Bath Chute Bar, No. 1.	12,633	$0 25	$3,158 25	......	......	......	$3,158 25	......	......	2.0	2,468	140	4.0	
1877..	July..............	Bath Chute Bar, No. 2	7,178	25	1,794 50	2 15	$10 00	$22 50	1,817 00	......	......	2.2	1,200 1,400 800	60 80 60	4.0 4.0	6¼ days' suspension.
1877..	July, August, and September.	Devil's Elbow Bar....	16,312	25	4,078 00	2 40	10 00	22 66	4,104 66	......	......	1.8	1,000	40	......	
1877..	September and October.	Pear Shoals..........	8,527	25	2,131 75	10	10 00	1 67	2,133 42	......	......	2.5	1,600	80	4.0	One dredge suspended 11 days.
1877..	October...........	Otwell's Bar..........	636	25	159 00	10	10 00	1 67	160 67	......	......	2.0	220	40	4.0	Suspended Oct. 27, resumed April 13.
1878..	April, May, and June.	Fisher's Island Bar...	17,760	25	4,440 00	1 35	10 00	15 33	4,455 83	......	......	2.0	3,500	100	4.0	Suspended May 6, resumed June 26.
1877..	June..............	Bath Chute*..........	11,000	25	2,750 00	......	......	......	2,750 00	......	......	......	......	......	......	Suspended June 28, contract extended to June 29.
	Total..........	....	....	.....	....	.....	......	......	18,579 83							

* Work done in fiscal year ending June 30, 1877.

bstract of contract for improving the Illinois River in force during the fiscal year ending June 3, 1878.

ame and residence of contractor.	Date of contract.	Subject of contract.	Earth excavation (dredging), per cubic yard.	For furnishing and driving piles, per linear foot.	For furnishing and putting in place.		For working one or more dredges, manned and equipped, each per hour.	Remarks.
					Brush, per cord.	Rubble-stone, per cubic yard.		
I. S. Brown, Hamilton, Hancock County, Ill.	June 22, 1877	Material and labor.	$0 25	$0 15	$2 50	$2 00	$10 00	Contract extended to June 29, 1878.

Water record Illinois River improvement, from July 1, 1877, *to June* 30, 1878.

Day.	1877.						1878.					
	July.	August.	September.	October.	November.	December.	January.	February.	March.	April.	May.	June.
1	8.9	3.4	1.6	0.5	4.6	8.2	11.7	7.8	12.6	10.7	9.7	10.8
2	8.9	3.7	1.6	0.6	4.7	8.3	11.9	7.8	12.8	10.5	10.0	10.9
3	9.0	3.8	1.5	0.6	4.7	8.3	12.0	7.7	13.0	10.3	10.4	11.4
4	9.2	3.5	1.4	0.5	4.7	8.4	12.1	7.7	13.2	10.1	10.7	11.5
5	9.4	3.2	1.4	0.5	4.7	8.4	12.2	7.7	13.2	10.0	10.9	11.7
6	9.6	2.9	1.4	0.4	4.7	8.4	12.2	7.7	13.2	9.8	11.2	12.0
7	9.7	2.8	1.4	0.4	4.7	8.4	12.1	7.6	13.1	9.6	11.4	12.3
8	9.7	2.7	......	0.5	4.8	8.4	11.9	7.6	13.1	9.5	11.4	12.5
9	9.7	2.7	......	0.4	4.8	8.4	11.8	......	13.0	9.4	11.5	12.8
0	9.7	2.6	0.9	0.5	4.9	8.3	11.7	8.7	13.1	9.2	11.5	13.0
1	9.6	2.4	0.8	0.5	5.0	8.3	11.5	8.7	13.3	9.0	11.4	13.2
2	9.5	2.3	0.8	0.6	5.1	8.3	11.3	8.5	13.3	6.7	11.5	13.3
3	9.3	2.4	0.8	0.6	5.2	8.2	11.0	8.5	13.3	6.6	11.4	13.4
4	9.2	2.4	0.8	0.6	5.4	8.1	10.8	8.7	13.2	6.5	11.4	13.5
5	9.0	2.3	0.8	0.7	6.0	8.1	10.6	9.1	13.1	6.5	11.2	13.7
6	8.8	2.3	0.9	0.7	6.5	8.0	10.3	9.3	13.0	6.7	11.0	13.7
7	8.6	2.2	0.9	0.7	6.8	8.0	10.1	9.6	12.8	7.2	10.9	13.7
8	8.3	2.2	0.8	0.8	6.8	8.2	9.9	9.7	12.7	7.0	10.7	13.6
9	8.0	2.1	0.8	1.2	6.8	8.7	9.7	9.9	12.6	6.8	11.1	13.4
0	7.7	2.0	0.7	1.6	6.8	9.0	9.4	10.1	12.5	7.5	11.2	13.1
1	7.3	1.9	0.7	2.2	7.0	9.0	9.3	10.4	12.4	8.2	11.2	12.7
2	6.9	1.9	0.6	2.5	7.4	9.0	9.0	11.1	12.2	7.6	11.2	12.3
3	6.6	1.9	0.6	2.7	7.7	9.1	8.8	11.4	12.1	7.9	10.9	11.8
4	6.2	1.9	0.6	2.8	7.8	9.4	8.7	11.7	12.0	9.4	10.7	11.4
5	5.8	1.7	0.6	2.6	7.8	9.9	8.5	11.8	11.8	9.8	10.7	11.1
6	5.3	1.6	0.5	2.6	7.8	10.3	8.3	11.9	11.6	9.9	10.7	10.7
7	4.9	1.6	0.4	3.5	8.0	10.7	8.2	12.1	11.4	9.8	10.8	10.3
3	4.5	1.5	0.5	......	8.0	10.9	8.3	12.4	11.3	9.6	10.8	9.9
	4.1	1.5	0.5	4.5	8.1	11.0	8.2	......	11.1	9.6	10.7	......
	3.7	1.7	0.5	4.8	8.1	11.3	8.1	......	11.0	9.5	10.6	......
	3.4	1.6	......	4.7	......	11.5	7.9	......	10.8	......	10.7	......
Mean	7.7	2.3	0.9	1.5	6.2	9.0	10.2	9.4	12.5	8.7	10.9	12.3

COMMERCIAL STATISTICS, ETC.

The work of improving the Illinois River is within the customs-district of New rleans. The length of section under improvement is 223 miles. The amount of cusoms revenue collected at the port of Saint Louis for the fiscal year ending June 30, 877, is $1,422,642; for the calendar year of 1877, $1,300,133. The enrolled tonnage of essels on the Illinois River aggregate the amount of 20,250 tons.

* * * * * * * *

Arrivals and departures of steamboats and barges at the port of Saint Louis in 1877.

Rivers, &c.	Arrivals.	Departures.
Upper Mississippi	834	[illegible]
Lower Mississippi	780	[illegible]
Illinois	252	[illegible]
Missouri	145	[illegible]
Ohio, Cumberland, and Tennessee	139	[illegible]
Total steamers	2,150	[illegible]
Barges and canal-boats	660	....

Tons of freight received	[illegible]
Tons of freight shipped	[illegible]

Statement showing the amount of freight in tons received and shipped at Saint Louis in

Rivers.	Received.	Shipped.
Upper Mississippi	136,715	[illegible]
Lower Mississippi	149,825	[illegible]
Illinois	104,200	[illegible]
Missouri	49,645	[illegible]
Ohio, Cumberland, and Tennessee	204,100	[illegible]

* * * * * * *

In concluding this report, I beg leave to refer to your favorable consideration several members of the engineering party. Sub-assistant S. R. Guyer has been on work since March, 1875; has become fully acquainted with the several details, an proves himself energetic, efficient, and faithful. E. D. Wyckoff, observer and computer, is a valuable acquisition to the party. James W. Jones is decidedly worth and fills his position with credit; his zeal in the care of public property is truly commendable.

I have no hesitancy in recommending all for advancement whenever for the inter of the work.

Most respectfully, your obedient servant,

R. A. BROWN,
Assistant Engineer.

Capt. G. J. LYDECKER,
Corps of Engineers.

APPENDIX CC.

ANNUAL REPORT OF MAJOR S. M. MANSFIELD, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1878.

UNITED STATES ENGINEER OFFICE,
Detroit, Mich., July 13, 1878.

GENERAL: I have the honor to forward herewith my annual reports relating to the works of harbor improvements under my charge for the fiscal year ending June 30, 1878.

Very respectfully, your obedient servant,

S. M. MANSFIELD,
Major of Engineers and Bvt. Lieut. Col., U. S. A.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

CC 1.

IMPROVEMENT OF CHARLEVOIX HARBOR, MICHIGAN.

Under contract of June 20, 1877, with Carkin and Stickney, work commenced June 30, and proceeded steadily and satisfactorily until August 31, when contract was closed. The work accomplished by Messrs. Carkin and Stickney was the removal of 23,436 cubic yards sand, gravel, &c., from the channel (deepening and widening it), and the building and placing of 3 cribs, each 50 feet by 20 feet by 10½ feet, in (new) south pier.

One crib in old south pier was found serviceable and was removed into line of new work, and connection with the shore, a distance of 159 feet, was made with brush-mattresses laid on the beach and weighted with gravel.

A severe storm in October showed that some protection was necessary for the bank of the river east of the north pier near the shore-line, to revent the sea from breaking through to destroy the north pier and the ld pile-dock; so, to preserve the work from damage, a timber framework inclosing a small quantity of brush with stone ballast was placed here.

The old north pier (left standing and utilized as a north pier), of a ength of 472 feet from shore-line, was partially refilled with brush and stone, received a few minor repairs, and was planked over, thus putting t in secure condition for the winter.

Thus far the *permanent work* built by the United States comprehends—

	Crib-work	Brush-work.
North side of channel and extensions	—— feet.	—— feet.
South side of channel and extensions	190 feet.	159 feet.
Total (without superstructure)	190 feet.	159 feet.

The north pier (old crib-work laid on the beach repaired by the United States) has a total length of 472 feet.

The south pier (new construction, excepting one crib of 40 feet length) has a total extension of 349 feet; falling short of the north pier about feet.

The piers are parallel and 150 feet apart.

After dredging was discontinued, viz, September 25, 1877, soundings taken developed a channel-way of 9 feet between piers and in the riv. This spring we find a narrow bar at shore-line with but 8 feet w on it.

Plans heretofore submitted call for the following-named improvements:

Dredging inside channel, &c., 130,000 cubic yards; removing old pier (south); building 950 feet north pier (cribs); building 550 feet south pier (cribs); building 25 feet pile-revetment—

At an estimated cost of	$186,00
Appropriated (1876–'78)	22,0
Unappropriated balance	164,0

In further continuance of the work of improvement here $30,000 could be profitably expended in the fiscal year ending June 30, 1880, in pier extension and channel widening and deepening.

OPERATIONS CONTEMPLATED FOR YEAR 1878–'79.

To construct and sink in the extension of the north pier 3 cribs, and t construct and place in the extension of the south pier 2 cribs. The cribs to be 50 feet by 20 feet by 16½ feet each.

To refill the old north pier with stone.

To put in position a slight apron of brush along the outer base of nor pier, extending about 300 feet from shore.

To place a similar apron of brush along the line of shore east fro end of present brush-work on south side of channel for a distance of feet, and to make such minor repairs to the present work as may b necessary.

Proposals for this work will be opened July 26, and contract will b awarded immediately thereafter.

The work is located in the Michigan collection-district, Michigan. It is situated the mouth of Pine River, which empties itself into Lake Michigan between Little an Grand Traverse Bays. The nearest port of entry is Grand Haven, Mich. The neare light-station is at Grand Traverse.

Statement of vessels entered and cleared from June 1, 1877, *to June* 1, 1878.

Entered: Number, 290; tonnage, 35,276.
Cleared: Number, 291; tonnage, 35,318.

Money statement.

July 1, 1877, amount available	$5,244 24	
Amount appropriated by act approved June 18, 1878	12,000 00	
		$17,24
July 1, 1878, amount expended during fiscal year		5,16
July 1, 1878, amount available		12,07
Amount (estimated) required for completion of existing project		164,00
Amount that can be profitably expended in fiscal year ending June 30, 1880.		30,00

C C 2.

IMPROVEMENT OF FRANKFORT HARBOR, MICHIGAN.

Under contract of June 12, 1877, with Mr. Robert M. Steel, 1 crib, 50 feet by 30 feet by 20½ feet, was placed in the extension of the south pier.

This crib (13 courses high) was sunk and securely ballasted by August 7, and the superstructure over it completed October 20, 1877, when contract with Mr. Steel was closed. To secure this crib in position 2 rock-elm piles were driven in the outer angles, and to properly connect the superstructure with the old work 5 piles were driven in the south side of this crib.

Additional courses of timber were framed over the cribs next east (inward) of the new crib, and 70,526 cords of stone were put into old crib-work. The south pile-revetment, near shore-line, received a plank sheeting and refilling where, through the open piling of the back row, the filling had washed out. In the heads of both piers additional stone-ballast was placed; in all, 35½ cords.

WORK CONSTRUCTED FROM JULY 1, 1867, TO JUNE 30, 1878.

	Crib-work.	Pile-work.
North side of channel and extensions	548 feet.	620 feet.
South side of channel and extensions	893 feet.	445 feet.
Total	1,441 feet.	1,065 feet.

The south pier is farther advanced by 150 feet than the north pier.

A bar with but 9½ feet water on it covers the approach to the harbor this spring, while the channel between the piers has at least 11 feet.

Recommendations periodically submitted since 1872 contemplate pier-extension at this point. $13,200 can be profitably expended in the fiscal year ending June 30, 1880.

Original estimate (1866) amended (1875)	$223,156 00
Appropriated and allotted (1866–'78)	209,956 00
Unappropriated balance	13,200 00

OPERATIONS CONTEMPLATED FOR YEAR 1878–'79.

To construct and sink in extension of south pier 1 crib, 50 feet by 30 feet by 20½ feet.

To construct and sink in extension of north pier 1 crib, 50 feet by 20 feet by 18½ feet.

To refill old work and make such minor repairs as may be found necessary.

Proposals for this work will be opened July 26, and contract will be awarded immediately thereafter.

The work is located in the Michigan collection-district, Michigan. The nearest port of entry is Grand Haven, Mich. The nearest light-house is at Point Betsey (Point Aux Becs Scies). A light is shown near head of south pier.

Statement of vessels entered and cleared from June 1, 1877, *to June* 1, 1878.

Entered: Number, 190; tonnage, 69,480.
Cleared: Number, 198; tonnage, 69,759.

Money statement.

July 1, 1877, amount available	$3,450 31	
Amount appropriated by act approved June 18, 1878	8,800 00	
		$12,250 3
July 1, 1878, amount expended during fiscal year		3,373
July 1, 1878, amount available		8,87
Amount (estimated) required for completion of existing project		13,200
Amount that can be profitably expended in fiscal year ending June 30, 1880.		13,200

CC 3.

IMPROVEMENT OF MANISTEE HARBOR, MICHIGAN.

Under contract of June 16, 1877, with Squier and White, the point of sand in the bend of the river on north side was dredged away and the exposed bank faced with a pile-revetment for a length of 420 feet. The work is substantial and presents a good appearance. Under this contract the total amount of material dredged and removed from the point and channel was, sand 48,610 cubic yards, and slabs 188 cubic yards. The contract was closed November 30, 1877.

Some stone was transferred early in the season from inner end of north pile-revetment to the outer end of north pier for use as crib-ballast and riprap; and, later, the old work received a reballasting, there being used for that purpose 32 cords of stone.

As a precautionary measure, with a view to protecting the work from fire, sand was scraped over the sawdust at back of north pile-revetment at a trifling cost.

On March 13, 1878, was received a petition and letters of certain lumber manufacturers, &c., of Manistee, setting forth the condition of Manistee Harbor, and urging the necessity of dredging away the bar at the entrance at the earliest time. This petition, &c., was forwarded the same day to the Chief of Engineers, with report.

Under the authority given by the Chief of Engineers, Messrs. Squier and White, of Grand Haven, were engaged to remove the bar, the necessary dredging to be done for 14 cents per cubic yard of material removed, and a contingent allowance of $10 per day for time lost in consequence of rough weather.

In the last days of March (28 to 31) an examination was made, and soundings covering all the shoal water near the entrance to the harbor taken. Upon the shoal was found not over 8 feet of water.

The work of removing the bar under the terms agreed upon began April 6, and continued until funds were exhausted, May 15, leaving a channel of good width and depth.

WORK CONSTRUCTED FROM JULY 1, 1867, TO JUNE 30, 1878.

	Crib-work.	Pile-work
North side of channel and extensions	788 feet.	1,338 feet
South side of channel and extensions	788 feet.	495 feet
Total	1,576 feet.	1,833 feet

The north pier is 100 feet farther advanced into the lake than the south pier.

The present depth in channel and on bar where dredged is about 1 feet.

Recommendations annually submitted since 1873 call for the expenditure of such amounts as may be appropriated in pier extension, and according to the estimates heretofore made the balance required for that purpose is $61,771, of which amount the sum of $30,000 could be very profitably expended in the fiscal year ending June 30, 1880, in extending piers.

Original estimate (1866) amended (1875)	$234,771 00
Appropriated and allotted (1866-'78)	173,000 00
Unappropriated balance	61,771 00

OPERATIONS CONTEMPLATED FOR YEAR 1878-'79.

To construct and sink in extension of the north pier two cribs, each 50 feet by 24 feet by 22½ feet.

To construct and sink in extension of the south pier two cribs, each 50 feet by 24 feet by 18½ feet.

To refill piers, replace old and broken timbers, relevel and riprap piers as required.

Proposals for this work will be opened July 26, and contract will be awarded immediately thereafter.

The work is located in the Michigan collection-district, Michigan. The nearest port of entry is Grand Haven, Mich. The nearest light-house is the Manistee light (discontinued October 15, 1875). A light is shown near head of south pier.

Statement of vessels entered and cleared from June 1, 1877, to June 1, 1878.

Entered: Number, 1,236; tonnage, 287,906.
Cleared: Number, 1,250; tonnage, 289,564.

Money statement.

July 1, 1877, amount available	$7,169 79	
Amount appropriated by act approved June 18, 1878	15,000 00	
		$22,169 79
July 1, 1878, amount expended during fiscal year		6,452 53
July 1, 1878, amount available		15,717 26
Amount (estimated) required for completion of existing project		61,771 00
Amount that can be profitably expended in fiscal year ending June 30, 1880.		30,000 00

C C 4.

IMPROVEMENT OF LUDINGTON HARBOR, MICHIGAN.

Under contract of June 13, 1877, with Duncan Dewar, two cribs were placed in extension of the south pier. Both cribs (each 15 courses high) were sunk and securely ballasted by July 16, and the superstructure over them completed September 29, when contract with Mr. Dewar was closed.

A slight break in the superstructure on the channel side of north pier, made by collision of the steamer Dix, was repaired. A portion of this north pier (about 150 feet from its eastern end) which had settled badly along the channel side was releveled. The outer crib of north pier which had settled badly was also releveled, refilled, and riprapped; and the crib of the south pier, upon which the light-house stands, received additional stone ballast.

In the rear of the south-side revetment, below the ferry, a filling of edgings and shingle rubbish was placed to prevent any further washing and deepening of the water behind the work.

The projecting portion of old south-pier head, which was damaged by ice and drift-wood, was protected from further danger by a row of piles driven so as to cover the angle formed by the projecting pier-head crib and the narrower crib ahead of it. The superstructure over these piles was connected with the crib superstructure and the angle then filled with stone.

To prevent dislocation of the outer crib of south pier, two rock-elm piles were driven in the exterior angles of the crib.

The United States dredging apparatus commenced work October 22, and up to the 17th November succeeded in removing 6,000 cubic yards sand, &c., from the channel, leaving an available water-way of about 13 feet. The machinery was then laid up for the winter.

A new bulkhead and new filling were placed at each end of south pile-revetment, and the outer crib and other defective points in the south pier were refilled with 27¼ cords of stone.

WORK CONSTRUCTED FROM JULY 1, 1867, TO JULY 30, 1878.

	Crib-work.	Pile-work.
North side of channel and extensions	743 feet.	....
South side of channel and extensions	969 feet.	704 feet.
Total	1,712 feet.	704 feet.

The south pier farther advanced by 200 feet than the north pier. We have good 12 feet water here now.

Recommendations for pier extension have been made in annual reports, and, together with the estimate of 1875, are here renewed. The unappropriated balance of $11,000 can be profitably expended during the year ending June 30, 1880.

Original estimate (1866) amended (1875)	$202,185 00
Appropriated and allotted (1866–'78)	191,185 00
Unappropriated balance	11,000 00

OPERATIONS CONTEMPLATED FOR YEAR 1878–'79.

To construct and sink in extension of the north pier 2 cribs, each 50 feet by 24 feet by 22½ feet.

To construct and sink in extension of the south pier 1 crib 50 feet by 30 feet by 24½ feet.

To refill old work and make such minor repairs as may be found necessary.

Proposals for this work will be opened July 26, and contract will be awarded immediately thereafter.

This work is situated in the Michigan collection-district, Michigan. The nearest port of entry is Grand Haven, Mich. The nearest light-house is at Grande Point au Sable. A light is shown near head of south pier.

Statement of vessels entered and cleared from June 1, 1877, to *June* 1, 1878.

Entered: Number, 859; tonnage, 145,186.
Cleared: Number, 875; tonnage, 147,616.

Money statement.

July 1, 1877, amount available	$4,043 03	
Amount appropriated by act approved June 18, 1878	15,000 00	
		$19,043 03
July 1, 1878, amount expended during fiscal year		3,325 77
July 1, 1878, amount available		15,717 26
Amount (estimated) required for completion of existing project		11,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1880.		11,000 00

C C 5.

IMPROVEMENT OF PENTWATER HARBOR, MICHIGAN.

Under the contract of June 16, 1877, with Squier and White, for dredging sand, removing old slab-work, and building revetment, work commenced the latter part of July. Steady progress was made until the completion of the work, December 1, 1877, at which time (under this contract) we had an extension of the north pile-pier 552 feet in an easterly direction, of which pile-work extension 106 feet is pile-pier and 446 feet pile-revetment. The amount of slabs removed from line of new work was 4,937 cubic yards; and the sand excavated about and in channel was 15,901 cubic yards, a water-way to the depth of about 12 feet having been dredged through the middle of the channel.

Slight repairs were made to the crib-work of the north pier, and the outer crib of the same pier was re-ballasted with 68 cords of stone and planked over.

Fifty feet of sheet-planking was framed to the defective portion of the south pile revetment, near the shore-line.

The 3 cribs at east end of south pier received a filling of brush, slabs, and stone at a small cost.

WORK CONSTRUCTED FROM JULY 1, 1867, TO JUNE 30, 1878.

	Crib-work.	Pile-work
North side of channel and extensions	290 feet.	882 feet.
South side of channel and extensions	608 feet.	1,137 feet.
Total	898 feet.	2,019 feet.

The north pier farther advanced by 130 feet than the south pier.

The shoalest water this spring is 9 feet for a short distance near the shore-line.

The recommendations and estimates made annually since 1873 are here renewed. The unappropriated balance of $29,200 can be profitably expended in the fiscal year ending June 30, 1880, in completing revetment and pier extension.

Original estimate (1866) amended (1873)	$192,020 00
Appropriated and allotted (1866-'78)	162,820 00
Unappropriated balance	29,200 00

OPERATIONS CONTEMPLATED FOR YEAR 1878-'79.

To build 600 feet of 14-feet pile revetment, extending north pier in an easterly direction.

To refill old work and make such minor repairs to piers as may be found necessary.

Proposals for this work will be opened July 26, and contract will be awarded immediately thereafter.

The work is located in the Michigan collection-district, Michigan. The nearest port of entry is Grand Haven, Mich. The nearest light-house is at Petite Point au Sable. A light is shown near head of south pier.

Statement of vessels entered and cleared from June 1, 1877, *to June* 1, 1878.

Entered: Number, 255; tonnage, 25,696.
Cleared: Number, 260; tonnage, 26,809.

Money statement.

July 1, 1877, amount available	$3,871 30	
Amount appropriated by act approved June 18, 1878	10,000 00	
		$13,871 30
July 1, 1878, amount expended during fiscal year		3,126 55
July 1, 1878, amount available		10,744 75
Amount (estimated) required for completion of existing project		29,200 00
Amount that can be profitably expended in fiscal year ending June 30, 1880		29,200 00

C C 6.

IMPROVEMENT OF WHITE RIVER HARBOR, MICHIGAN.

The United States dredging apparatus began work the 9th of September, and up to the time of leaving for Ludington Harbor, October, 18, succeeded in removing 8,580 cubic yards of material from the channel, leaving an available water-way of 11 feet.

Work upon the south pile-pier near the shore-line was commenced September 20, and was prosecuted until funds were exhausted, October 19, 1877. This work consisted of removing the old filling, and replacing it with new filling—brush mattresses, edgings, and stone—for a distance of 200 linear feet of pier-work westward from the shore-line, that being the most defective portion.

In addition, 28¾ cords of stone were placed in the pier-heads and other places necessary as ballast.

WORK CONSTRUCTED FROM JULY 1, 1867, TO JUNE 30, 1878.

	Crib-work.	Pile-work.
North side of channel and extensions	....	1,685 feet.
South side of channel and extensions	150 feet.	2,070 feet.
Total	150 feet.	3,755 feet.

The south pier the longer by 50 feet. Available depth of water this spring in the channel and on bar, 10 feet.

In continuance of improvements here, as suggested in previous reports, (pier extension), the unappropriated balance of the estimate of 1873, $19,891.56, together with the estimate of $5,000 for dredging, or $24,891.56, can be profitably expended in the fiscal year ending June 30, 1880.

Original estimate (1866) amended (1873)	$220,441 56
Appropriated and allotted (1866–'78)	195,550 00
Unappropriated balance	24,891 56

OPERATIONS CONTEMPLATED FOR YEAR 1878–'79.

To construct and sink a south-pier extension, 1 crib 50 feet by 24 feet by 20½ feet.

To overhaul and refill the pile-piers with brush, edgings, and stone.

To make minor repairs to piers.

Proposals for this work will be opened July 26, and contracts will be awarded immediately thereafter.

The work is located in the Michigan collection-district, Michigan. It is situated at the White River light-house. The nearest port of entry is Grand Haven, Mich.

Statement of vessels entered and cleared from June 1, 1877, to June 1, 1878.

Entered: Number, 837; tonnage, 102,509.
Cleared: Number, 837; tonnage, 102,789.

Money statement.

July 1, 1877, amount available	$2,929 67	
Amount appropriated by act approved June 18, 1878	12,000 00	
		$14,929 67
July 1, 1878, amount expended during fiscal year		2,802 02
July 1, 1878, amount available		12,127 65
Amount (estimated) required for completion of existing project		24,891 56
Amount that can be profitably expended in fiscal year ending June 30, 1880		24,891 56

C C 7.

IMPROVEMENT OF MUSKEGON HARBOR, MICHIGAN.

The work under contract of June 16, 1877, with Culbert and Hopkins, for the building and placing of 2 cribs, each 50 feet by 30 feet by 26½ feet, in extension of the south pier, commenced early in July, and by the 31st of August both cribs (each 20 courses high) were sunk and securely ballasted. The superstructure and necessary stone riprap were added from time to time until final completion of the work, when contract was closed, December 1, 1877.

Several openings and defective places in both piers were repaired and refilled, and the 88-feet long gap in old slab pier (about 400 feet east of north government pier) was closed by the construction of a new slab dock therein.

To secure the position of the outer crib (new work of Culbert and Hopkins on south side) two white-oak piles, each 46 feet long, were driven in the outer angles of the crib.

Thirty cords of stone were put into the empty pockets of crib-work near the end of north pier.

WORK CONSTRUCTED FROM JULY 1, 1867, TO JUNE 30, 1878.

	Crib-work.	Pile-work.
North side of channel and extensions	589 feet.	385 feet.
South side of channel and extensions	530 feet.	384 feet.
Total	1,119 feet.	769 feet.

The south pier 300 feet longer than the north pier.

The available depth of water between piers this spring, 14 feet; no outside bar.

No appropriation was asked for the fiscal year 1878–'79, and no appropriation was given.

Original estimate (1866) amended (1875)	$152,898 04
Appropriated and allotted (1866–'78)	144,000 00
Unappropriated balance	8,898 04

Which can be profitably expended for pier-extension—one crib, 50 feet, to north pier—and in repairs to piers, as may be required, in the fiscal year ending June 30, 1880.

OPERATIONS CONTEMPLATED FOR YEAR 1878–'79.

North pier.—Reconstruction of superstructure over outer crib and over part of inner crib next to it, closing and refilling intervals between these cribs, refilling superstructure with stone, and placing fenders around pier-head crib.

South pier.—Replace oak fenders on outer crib, refill some parts of the pier with brush and stone, and place plank-decking at certain points over exposed filling.

Proposals for this work will be opened July 26, and contract will be awarded immediately thereafter.

This work is located in the Michigan collection-district, Michigan. It is situated at the Muskegon light-house. The nearest port of entry is Grand Haven, Mich.

Statement of vessels entered and cleared from June 1, 1877, *to June* 1, 1878.

Entered: Number, 1,158; tonnage, 411,262.
Cleared: Number, 1,219; tonnage, 422,936.

Money statement.

July 1, 1877, amount available	$9,281 48
July 1, 1878, amount expended during fiscal year	4,888 02
July 1, 1878, amount available	4,393 46
Amount (estimated) required for completion of existing project	8,898 04
Amount that can be profitably expended in fiscal year ending June 30, 1880	8,898 04

C C 8.

IMPROVEMENT OF GRAND HAVEN HARBOR, MICHIGAN.

The contract of November 25, 1876, with James Caldwell, to place 3 cribs in extension of the north pier, progressed very slowly. This contract was to be completed the 1st of July, 1877, but an extension of time was granted the contractor. The first crib was placed July 7; the second crib, August 4; and the third and last crib September 13, 1877 (each crib 50 feet by 30 feet by 20½ feet).

The superstructure (6 courses high) over these cribs was completed November 17, 1877, when contract closed.

Three cargoes of stone (85 cords) were placed as riprap along the channel face of the south pier, rendering the pier perfectly stable; it is thought no further change need be anticipated in this line of pier.

A break in filling of the north pier, near the shore line, was repaired with 20 cords of edgings.

Regarding a bar formed across the entrance to this harbor during the past winter, I submit the following letter of Assistant Mower:

LETTER OF MR. S. C. MOWER, ASSISTANT ENGINEER.

GRAND HAVEN, MICH., *February* 26, 1878.

COLONEL: I have the honor to acknowledge the receipt of your letter of the 22d instant, in which you inquire as to the probable cause of the formation of the bar at the mouth of Grand River, and ask such further information as I may be able to furnish relative to this bar, and its effect upon the commerce of this port.

In reply, I have to state that during the months of September—the latter part of that month more properly—and October the prevailing hard winds come from the northwest. There was but little current in the river during this time, and the accumulation of sand at mouth of the harbor proceeded slowly until about the 1st of November, when the necessity for removing a portion of the sand became apparent.

I was asked by the agent of the transportation company if the government could do anything for their relief. My answer was, that there were no funds remaining over, and that I knew of no method of immediately relieving them.

I examined the bar and found that a middle ground had formed nearly opposite to and about 150 feet out from the middle of the opening between piers, upon which, at its shoalest place, there were but 11½ feet of water. The conformation of the bar at this time seemed to be mound-like and not very extensive.

By the middle of December, the steamers began to touch bottom when entering the harbor well to the southward of the range lights.

I went down and made further examination, and, to my surprise, I found that an immense body of sand had accumulated, and laid spread over the bottom fully 700 feet out from the piers, and extending quite across the opening, leaving 9 feet as the shoalest and 13½ as the deepest water.

The company decided to move at once; and the powerful wrecking-tug Leviathan arrived here and began work with her wheel about January 16. She remained until February 14, working but a small portion of the intervening time.

She has left a channel about 200 feet wide with 14½ feet of water, and this depth will probably remain, as the boats load so deep as to take all the water there is, and their wheels help the channel.

The inconvenience and damage to the line through the existence of this bar may be approximately derived from a consideration of the fact that there are four propellers, with an aggregate tonnage of 4,134 tons, besides two large barges, aggregating nearly 2,000 tons, running to this port in connection with the Detroit and Milwaukee Railroad. Two of the steamers carry grain exclusively, one carries grain and rolling freight, and one rolling freight alone. The aggregate grain capacity of the three steamers is 115,000 bushels.

From December 8, 1877, to February 23, 1878, there were 1,700,000 bushels of grain delivered; while with full loads, allowing the same number of trips, there would have been 2,127,000 bushels delivered.

These figures I get from the agent here, but from personal knowledge I can say that very many trips have been lost by reason of the unsafe water here, and the boats would not start out to take a risk; while with good water here the trip could have been made without question.

From my personal knowledge, together with the figures I have secured, I feel confident that fully 50 per cent. more trips would have been made than have been made had the entrance to the harbor been safe as it is in summer months.

This has been an exceptional year. There has not been any extensive ice formation along the beach, and, of course, no grounded ice outside to serve as a temporary pier extension, nor has there been any floating ice in the lake to break the force of the sea near the shore. There has been very little current in the river to force the deposits it carries down out into deep water.

While I am satisfied that a large body of sand is carried down the river, it is my opinion that this bar is created from sands which are swept from the northward along the shoals until it reaches the north pier, when it is swept around the end of the pier; and this process continued, as it has been this year, can only result in rendering the entrance to the harbor unsafe. Of course, the spring currents will remove the obstruction, but any mild winter is liable to witness a repetition of the trouble.

There appears to me no better means of obviating the difficulty than extension of the piers, especially the north pier, to the general 18-foot curve (which would add to the north pier about 450 feet), and running a wing or breakwater to the northward and at a right angle from it; the breakwater to be connected with the pier-head.

This winter trade is the backbone of the Detroit and Milwaukee Road, and it is of great local as well as general importance that this harbor be rendered safe at all seasons.

I have no answer to my letter to Mr. Wilkins as yet, but should it arrive I may be able to give some further information, especially as to the cost of removing the bar.

Very respectfully, your obedient servant,

S. C. MOWER.

Bvt. Lieut. Col. S. M. MANSFIELD,
Major Corps of Engineers.

WORK CONSTRUCTED FROM JULY 1866, TO JUNE 30, 1878.

	Crib-work.	Pile-work
North side of channel and extensions	450 feet.	2,108 feet
South side of channel and extensions	424 feet.	3,035 feet
Total	874 feet.	5,143 feet

The north pier the longer by 50 feet.

The deepest water on the bar this spring is 15½ feet.

Recommendations heretofore made for pier extension and renewals carry an estimate for the completion of the work at this harbor, less amount appropriated June 18, 1878, of $29,148.96; and this amount can be profitably expended in the fiscal year ending June 30, 1880.

Original estimate (1866) amended (1878)	$323,900 11
Appropriated, allotted, transferred, (1866–'78)	294,751 15
Unappropriated balance	29,148 96

OPERATIONS CONTEMPLATED FOR YEAR 1878–'79.

To construct and sink in extension of the north pier 3 cribs 50 feet by 30 feet by 18½ feet without superstructure.

To make necessary repairs, especially to the south pier, in the way of overhauling and refilling the old work, and replacing old or broken timbers in the piers.

Proposals for this work will be opened July 26, and contract will be awarded immediately thereafter.

The work is located in the Michigan collection-district, Michigan. Grand Haven is the port of entry. It is situated at the Grand Haven lights.

Statement of vessels entered and cleared from June 1, 1877, to June 1, 1878.

Entered: Number, 955; tonnage, 410,857.
Cleared: Number, 960; tonnage, 422,440.

Money statement.

July 1, 1877, amount available	$3,003 39	
Amount appropriated by act approved June 18, 1878	15,000 00	
		$18,003 39
July 1, 1878, amount expended during fiscal year		3,003 18
June 1, 1878, amount available		15,000 21
Amount (estimated) required for completion of existing project		29,148 96
Amount that can be profitably expended in fiscal year ending June 30, 1880.		29,148 96

C C 9.

IMPROVEMENT OF BLACK LAKE HARBOR, MICHIGAN.

Work began under contract with Messrs. Squier and White, June 16, 1877. The contractors placed a crib 50 feet by 24 feet by 17½ feet in the extension of south pier September 14, and completed the building of the superstructure thereon November 17, 1877. This crib settled very much out of shape during the continuous heavy weather immediately following its sinking; and when the work of superstructing was commenced the outer end was 4 feet below water. It was raised stick by stick and the superstructure gradually drawn into shape, so that from the water-line up the alignment is very good. Under this contract there were 35,775 cubic yards of sand, &c., dredged and removed from channel-way. The contract was closed November 17, 1877.

Seven hundred and one running feet of revetment were cleared of old filling and to the water-level filled anew with brush-mattress work. This effectually stopped all action of the sea behind the work. A "sink-pier" of brush was placed outside the south pier and shore-line where the work was devoid of filling. The effect has been to entirely stop the flow of sand and water through the pier, and to advance the shore-line over 20 feet.

While the dredge (Squier & White's) was at work close under the west end of the south revetment, stone was recovered sufficient to fill over 100 linear feet of the work where it was entirely empty, and leave about 25 cords for other places in the pier.

The work of overhauling and refilling in the revetments was completed September 20.

A break occurred at the shore-line, in the south pier, and to stop it 700 feet, board-measure, of pine plank, and 9 cords of shingle-cuttings were used.

WORK CONSTRUCTED FROM AUGUST, 1867, TO JUNE 30, 1878.

	Crib-work.	Pile-work.
North side of channel and extensions	598 feet.	1,095 feet.
South side of channel and extensions	748 feet.	920 feet.
Total	1,346 feet.	2,015 feet.

The south pier 50 feet longer than the north pier.

Soundings of November 19, 1877, show an available water-way of 9 feet in channel. This spring we have the channel shoaled in one place to 8 feet.

The recommendations heretofore made are here renewed, and the unappropriated balance of $22,000 can be profitably expended in extending piers during the fiscal year ending June 30, 1880.

Original estimate (1866)	$106,238 04
Original appropriation (1866–'67)	106,615 31
Estimates of 1869, amended to 1877	119,000 00
Appropriated from 1869 to 1878	97,000 00
Unappropriated balance	22,000 00

OPERATIONS CONTEMPLATED FOR YEAR 1878–'79.

To construct and sink in extension of the south pier 1 crib 50 feet by 24 feet by 22½ feet.

To construct and sink in extension of the north pier 2 cribs, each 50 feet by 24 feet by 20½ feet, and make necessary repairs to piers.

Proposals for this work will be opened July 26, and contract will be awarded immediately thereafter.

The work is located in the Michigan collection-district, Michigan. It is situated at the Holland light (pier-head light near end of south pier). The nearest port of entry is Grand Haven, Mich.

Statement of vessels entered and cleared from June 1, 1877, *to June* 1, 1878.

Entered: Number, 169; tonnage, 8,843.
Cleared: Number, 175; tonnage, 8,995.

Money statement.

July 1, 1877, amount available	$10,482 15	
Amount appropriated by act approved June 18, 1878	10,000 00	
		$20,482 15
July 1, 1878, amount expended during fiscal year		9,779 57
July 1, 1878, amount available		10,702 58
Amount (estimated) required for completion of existing project		22,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1880		22,000 00

C C 10.

IMPROVEMENT OF SAUGATUCK HARBOR, MICHIGAN.

The only work done here during the year consisted of the handling and placing of stone lightered from the south to the north pier, and used as ballast at outer end of north pier, at a cost of $20.50.

In October and November, 1877, vessels entering the harbor had trouble with the sands from the north side, forming shoals across the channel, leaving a narrow space—50 feet—for an entrance. An extension of the north pier and a thorough filling of the present work is thought to be the proper remedy for this trouble.

WORK CONSTRUCTED FROM AUGUST, 1869, TO JUNE 30, 1878.

	Pile pier.	Pile revetment.
North side of channel and extensions	400 feet.	335 feet.
South side of channel and extensions	280 feet.	2,770 feet.
Total	680 feet.	3,105 feet.

Protecting south slab-pier with piles, 620 feet of pier.

The south pier is 300 feet longer than the north pier.

The depth of water is from 9 to 10 feet.

The unappropriated balance of the existing estimate for the completion of the work is $35,958.74. An appropriation of $10,000 is recommended for expenditure in the next fiscal year for pier-extension.

Original estimate (1867) amended (1876)	$136,397 74
Appropriated and allotted (1868-'78)	100,439 00
Unappropriated balance	35,958 74

OPERATIONS CONTEMPLATED IN YEAR 1878-'79.

To refill about 300 feet of north pile-pier with brush made into a mattress, built in place, weighted with stone; and some slight repairs will be made to the south pier.

This work will be done by hired labor, cutting the brush in the vicinity, where it is abundant, and the stone will be purchased in open market.

Arrangements have been made for the immediate prosecution of the work.

This work is located in the Michigan collection-district, Michigan. It is situated at the Kalamazoo light. The nearest port of entry is Grand Haven, Mich.

Statement of vessels entered and cleared from June 1, 1877, *to June* 1, 1878.

Entered: Number, 244; tonnage, 37,003.
Cleared: Number, 241; tonnage, 36,727.

Money statement.

July 1, 1877, amount available	$427 21	
Amount appropriated by act approved June 18, 1878	2,500 00	
		$2,927 21
July 1, 1878, amount expended during fiscal year	412 13	
July 1, 1878, outstanding liabilities	9 75	
		421 88
July 1, 1878, amount available		2,505 33
Amount (estimated) required for completion of existing project		35,958 74
Amount that can be profitably expended in fiscal year ending June 30, 1880		10,000 00

C C II.

IMPROVEMENT OF SOUTH HAVEN HARBOR, MICHIGAN.

The work under way at the end of the last fiscal year was continued and progressed satisfactorily until the funds were exhausted.

In August the entire removal of the old slab-dock was completed, and a commencement made in constructing new revetment to make secure shore connection from the outer crib-work. The dredging of the channel-cuts was completed the end of August. In all, the United States dredge removed 5,010 cubic yards of old slab-pier, and 22,510 cubic yards sand, &c., from in and about the channel.

The work connecting the crib-work with the shore line was completed October 3. The work accomplished covers 144½ linear feet of pile-revetment, the front or channel row of which is extended eastward 171½ feet farther, thus virtually giving 316 linear feet of new revetment and making substantial connection at the shore line with the outer work. That portion of the pile-work extending east from the 14 feet pile-revetment is capped, secured with wale and binder, and is backed, as in the balance of the work, by a plank-beam composed of hemlock 2 inches by 8 inches. This is backed by brush filling and the old filling leveled in upon the whole, making a substantial work.

During a gale immediately after the completion of the work here, in the early part of October, not less than 200 cords of stone washed out of the piers by the heavy sea. The stone was taken out down to the water surface, and in some places a little below; the most of it being washed out of the narrow crib-pier. The beach north of pier washed away a little, but the north revetment sustained no damage. On the south side, south of south pier, about 60 feet of the brush-bank thrown up by the dredge was carried away, leaving the south revetment exposed. Except the settling of the filling in the two outer pockets (which were immediately refilled), the new south revetment remained unimpaired.

At the end of the season's work there was a depth of 9 feet in the channel from entrance to the warehouse. This spring the channel has barred again to about 7½ feet for a short distance between the piers.

WORK CONSTRUCTED FROM 1867 TO JUNE 30, 1878.

	Crib-work.	Pile-work.
North side of channel and extensions	600 feet.	525 feet.
South side of channel and extensions	502 feet.	316 feet.
Total	1,102 feet.	841 feet.

The north pier the longer by 100 feet than the south pier.

The balance remaining unappropriated, viz, $60,000, is considered sufficient to complete all permanent improvements at this harbor under the present project; $25,000 of this balance can be profitably expended during the fiscal year ending June 30, 1880, in extending the piers and deepening the channel.

Original estimate (1866) amended (1877)	$202,000 00
Appropriated and allotted (1867-'78)	142,000 00
Unappropriated balance	60,000 00

OPERATIONS CONTEMPLATED FOR YEAR 1878-'79.

To dredge away slab-piles, brush, &c., of old piers, and also dredge sand in channel, about 30,000 cubic yards.

To construct about 450 feet of plank-beam revetment, extending north revetment in an easterly direction.

To make necessary repairs to piers, refilling and planking.

Proposals for this work will be opened July 26, and contract will be awarded immediately thereafter.

This work is located in the Michigan collection-district, Michigan. It is situated at the South Haven light. The nearest port of entry is Grand Haven, Mich.

Statement of vessels entered and cleared from June 1, 1877, *to June* 1, 1878.

Entered: Number, 222; tonnage, 20,743.
Cleared: Number, 222; tonnage, 20,810.

Money statement.

July 1, 1877, amount available	$3,914 92	
Amount appropriated by act approved June 18, 1878	12,000 00	
		$15,914 92
July 1, 1878, amount expended during fiscal year		3,814 90
July 1, 1878, amount available		12,100 02
Amount (estimated) required for completion of existing project		60,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1880.		25,000 00

C C 12.

IMPROVEMENT OF SAINT JOSEPH HARBOR, MICHIGAN.

The crib (50 feet by 24 feet and 14 courses high) sunk by Messrs. Culbert & Hopkins, under contract of November 28, 1876, in extension of the north pier, was superstructured, filled with stone, and decked over by the 21st of July, 1877, when contract was closed.

One load of stone (31.64 cords) was filled in the crib just interior to the new one placed by Culbert & Hopkins on north side to supply a deficiency.

With the approval of the Chief of Engineers certain repairs were made to the work, as follows:

During October and November, despite the rough weather, the north pier was leveled up, filled with stone, and decked over in such a manner as to protect the stone ballast. A few bad timbers in the superstructure were replaced by new ones, and at the outer end a protection of stone riprap was placed. The south pier was also repaired in the way of re-ballasting, and the open piling was closed in part by uprights let in between the piles and fastened by screw-bolts to the timbers composing the superstructure.

The continuous rough weather and ice so impeded the work that on the 15th of December it was discontinued.

The north pier at shore-line was left in a condition about the same as reported in last annual report; but at the outer end it was in good shape.

The water was good, there being from 15 to 17 feet in the best approaches.

Timber, bolts, and spikes remain on hand to continue the work of repairs on north pier.

WORK CONSTRUCTED FROM 1866 TO JUNE 30, 1878.

North side and extensions, 350 feet crib-work (50 feet lost, 1877).
South side and extensions, 616 feet pile-work.
Wing-dam in river, 528 feet pile-work.
Reconstruction of north pier (1866-'67), 409 feet and over.
Reconstruction of south pier (1866-'67), 200 feet and over.

There is at present a good depth of water here.

The existing project looks to an extension of the north pier; $4,216.71 of the estimate remains unappropriated for this purpose, and can be profitably expended in the fiscal year ending June 30, 1880.

The recommendations and estimates for Saint Joseph River (Benton Harbor) of last year are renewed.

Original estimate (1866-'77)	$137,216 71
Appropriated (1866-'78)	118,000 00
Unappropriated balance	19,216 71

OPERATIONS CONTEMPLATED FOR YEAR 1878-'79.

To construct and sink 2 cribs in extension of the north pier; one to be 50 feet by 24 feet by 22½ feet, and the other to be 50 feet by 30 feet by 22½ feet.

To refill old work and make the necessary repairs to piers.

Proposals for this work will be opened July 26, and contract will be awarded immediately thereafter.

This work is located in the Michigan collection-district, Michigan. It is situated at the Saint Joseph lights. The nearest port of entry is Grand Haven, Mich.

Statement of vessels entered and cleared from June 1, 1877, to June 1, 1878.

SAINT JOSEPH.

Entered: Number, 257; tonnage, 81,294.
Cleared: Number, 257; tonnage, 82,558.

BENTON HARBOR.

Entered: Number, 367; tonnage, 89,874.
Cleared: Number, 371; tonnage, 91,427.

Money statement.

July 1, 1877, amount available	$7,007 30	
Amount appropriated by act approved June 18, 1878	12,000 00	
		$19,007 30
July 1, 1878, amount expended during fiscal year		4,947 52
July 1, 1878, amount available		14,059 78
Amount (estimated) required for completion of existing project		19,216 71
Amount that can be profitably expended in fiscal year ending June 30, 1880.		19,216 71

APPENDIX D D.

ANNUAL REPORT UPON THE WORKS IN CHARGE OF MAJOR G. WEITZEL, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1878, BY CAPTAIN ALEXANDER MACKENZIE, CORPS OF ENGINEERS, TEMPORARILY IN CHARGE.

(Letter of transmittal under Appendix T.)

D D 1.

IMPROVEMENT OF SAINT MARY'S FALLS CANAL, MICHIGAN.

The progress of this work during the past fiscal year is given in the appended report of Mr. Alfred Noble, assistant engineer, in immediate charge of the improvement.

The contractors for laying the masonry of the new locks have used and are now using due diligence in prosecuting their work, and had the contractor for furnishing the stone been able to fulfill his contract by the specified date the lock-walls would have been completed during the present season. If the delivery of face-stone is finished this year the masonry will be completed early next season.

As during previous years, to secure the most perfect work, the government has continued to furnish cement for mortar and concrete. English Portland cement has been almost exclusively used for all face-stone and exposed parts of the work. For other portions of the wall the American natural and Portland cements have been used. Mr. Noble has carried on in connection with this work an elaborate system of tests of all cements furnished for the work. These tests will be continued until the completion of the work, and will furnish most valuable information as to the strength and quality of the various foreign and domestic brands.

The time has arrived when it is desirable for the good of the improvement that the management and control of the present canal should pass into the hands of the government.

To ascertain the present amount of the canal debt, which, in accordance with act of the Michigan legislature, is to be assumed by the United States as the only condition of transfer, a correspondence, of which the following is a copy, was entered into with his excellency Governor Croswell, of Michigan:

UNITED STATES ENGINEER OFFICE,
Detroit, Mich., April 30, 1878.

SIR: With a view of recommending in my next annual report the acceptance of the Saint Mary's Falls Canal in accordance with the joint resolution of the Michigan State legislature, approved April 3, 1869, I would respectfully ask for information as to the terms upon which the transfer will now be made, and the amount of indebtedness to be assumed by the government.

Very respectfully, your obedient servant,

G. WEITZEL,
Major of Engineers, U. S. A.

His Excellency CHARLES M. CROSWELL,
Governor of Michigan.

STATE OF MICHIGAN, EXECUTIVE OFFICE,
Adrian, May 1, 1878.

SIR: I have yours of the 30th ultimo asking information as to the terms upon which the Saint Mary's Falls Canal will be transferred to the United States, together with the amount of indebtedness thereon to be assumed by the General Government. I will call the attention of the canal board at its next meeting to the subject of your communication, and advise you of the action taken in reference thereto.

Yours, very respectfully,

CHAS. M. CROSWELL.

As no further information has been furnished, it is probable the board of control have not yet taken action in the matter.

The extremely low stage of water in the Saint Mary's River this year has rendered navigation more troublesome than usual. To remedy this as far as possible, authority was granted to remove the worst obstructions at three points in the river. This work has been commenced.

Work has been delayed during the past season by reason of the small amount of money available, and as the appropriation which becomes available July 1, 1878, is much less than the amount which it is thought could be profitably expended during the coming fiscal year, it is probable the work cannot be pushed forward quite as rapidly as was expected.

In order to complete this work according to the project, there remains to be appropriated the sum of $395,000.

For the sake of an economical and rapid prosecution of the work this entire sum should be appropriated for the fiscal year ending June 30, 1880.

The work will be prosecuted during the present working season under the present contracts, and by day's labor. If nothing unforeseen occurs, all the stone will be delivered, the lock-walls will be almost completed, work on the south pier will be continued, and a few obstructions will be removed from the river.

The operations contemplated in the fiscal year 1878–'79 are to complete the masonry of the new locks, build the gates, complete the pump-house, and continue work on the new south pier and the straightening of the canal.

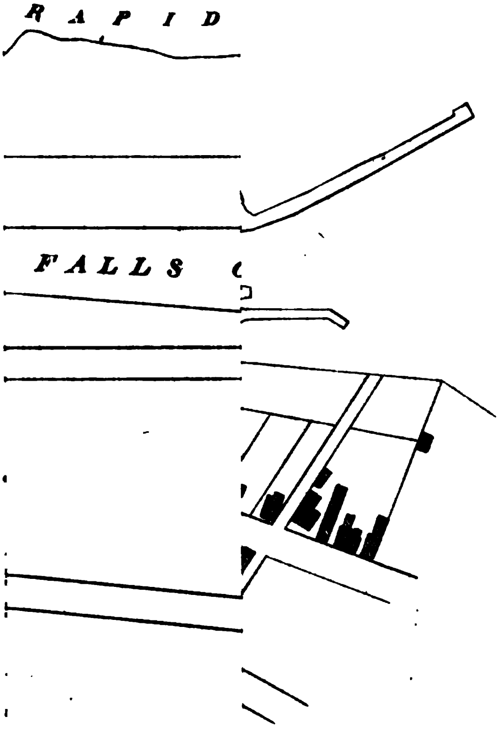
The whole amount appropriated since the enlargement of the canal was begun is as follows, viz:

1870	$150,000 00	1875	$200,000 00
1871	350,000 00	1876	130,000 00
1872	300,000 00	1878	175,000 00
1873	200,000 00		
1874	200,000 00	Total	1,705,000 00

Of this amount about $600,000 was expended before and during the excavation of the pit for the new locks, in widening and deepening the canal proper, revetting the sides of the enlarged canal, purchase of additional lands, and improving Saint Mary's River. Of the other $1,105,000 about $760,000 have been expended on the lock-pit, walls, other portions pertaining to new locks, and in straightening the canal at its upper entrance, and about $345,000 were on hand at the end of the fiscal year. Of this last amount $170,000 is covered by liabilities under contracts, and is therefore not available for the work which still remains to be done.

This work is located in the Superior collection-district, Michigan, at the Sault Ste. Marie subport of entry, and a short distance from Fort Brady. The nearest light-house is at Round Island, and the nearest port of entry is Marquette, Mich. The amount of money collected in the Superior district the last fiscal year was $10,808.52

The whole commerce of the great chain of Northern and Northwestern lakes will be benefited by the completion of this work.



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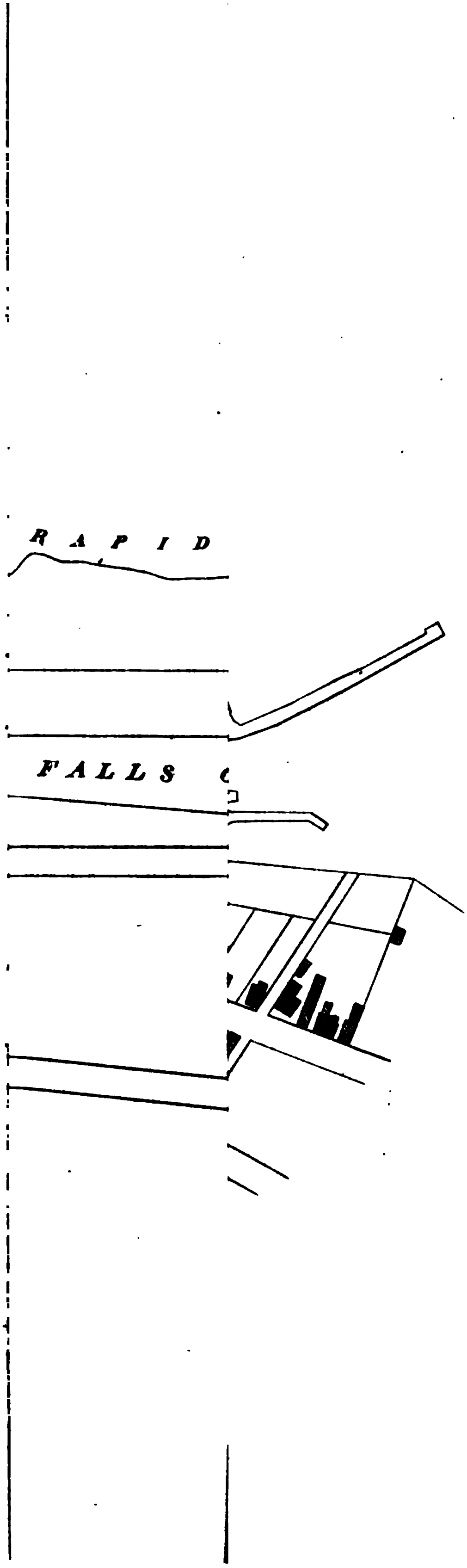
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Money statement.

July 1, 1877, amount available	$419,014 09	
Amount appropriated by act approved June 18, 1878	175,000 00	
		$594,014 09
July 1, 1878, amount expended during fiscal year		249,345 47
July 1, 1878, amount available		344,668 62
Amount (estimated) required for completion of existing project		395,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1880		395,000 00

REPORT OF MR. ALFRED NOBLE, ASSISTANT ENGINEER.

SAULT STE. MARIE, MICH.,
June 29, 1878.

CAPTAIN: I have the honor to submit the following report of operations at the Saint Mary's Falls Canal during the year ending June 30, 1878.

At the beginning of the year there were two contracts existing, one with Henry Van Vleck for furnishing face-stone, and one with Boyle & Roach for furnishing the backing and laying the masonry of the new lock. On July 9, 1877, a contract was made with C. S. Barker for dredging for the enlargement at the head of the canal from the line for the new south pier to the present channel. Some difficulty was apprehended in placing the pier, owing to the nature of the material on which it was to be founded; the framing and placing were therefore undertaken by hired labor.

The amount of work performed during the year is as follows:

Under the contract of May 29, 1875, 18,683.46 cubic yards of masonry have been laid and 6,853 cubic yards of earth have been placed behind the new lock-walls.

Under the contract of May 11, 1876, 128,512.23 cubic feet of face-stone have been delivered.

Under contract of July 9, 1877, 447.27 cubic yards of earth have been removed.

For the work of building the new south pier at the head of the canal 1,190 linear feet of crib-work have been built and 1,070 linear feet placed.

The cement for the walls of the new lock has been purchased in open market; 18,351 barrels have been received.

A shoal in the river channel 1 mile above the canal has been dredged to 13 feet of water.

A tracing showing the present condition of the improvement and a diagram of the stage of water during the year are attached.

Respectfully submitted.

ALFRED NOBLE,
Assistant.

Capt. A. MACKENZIE,
Corps of Engineers, U. S. A.

D D 2.

CONSTRUCTION OF HARBOR OF REFUGE, LAKE HURON, MICHIGAN.

The history and condition of the work are given in the appended report of Mr. C. P. Gilbert, who during the past year has, as assistant engineer, had the local charge of the improvement at the harbor of refuge.

At the beginning of the year two contracts were in force, one with Hemenway & Hays, of Painesville, Ohio, for continuing the breakwater, and one with C. S. Barker, of Sault Ste. Marie, Mich., for removing the wreck of schooner City of Buffalo and several dangerous bowlders from the harbor. These contracts were both completed during the year 1877. The work of this season has consisted simply in making repairs, as the available balance after closing Messrs. Hemenway & Hays's contract did not justify the commencement of new work.

The experience gained during the past year has not been sufficient to determine definitely the value of the opening left in the shore-arm of the breakwater. There is no harm in again postponing the question of this opening and obtaining further information.

In the last annual report on this work reference is made to the necessity of an act of Congress prescribing rules for the government of the harbor of refuge, Sand Beach, and to the necessity of having a harbor-master to regulate the vessels and enforce the laws.

A draught of an act was presented with the foregoing recommendation. Congress has as yet taken no action in the matter.

The number of vessels taking refuge in harbor is increasing yearly, and will continue to increase as the advantages of its protection become better known. As this number increases, the necessity for the laws asked for will increase.

The work of the present season will consist in building a superstructure over the cribs sunk last year, preparing the bottom in continuation of the lake arm of the breakwater, and increasing the available anchorage by dredging.

The work contemplated for the year 1878–'79 is to continue the lake arm of the breakwater by the sinking of cribs.

The estimated cost of this work was $1,452,550, but, as explained in last report, the actual cost will probably not exceed $855,000. Of this amount the following sums have been appropriated:

1871	$100,000 00	1876	$75,000 00
1872	100,000 00	1878	100,000 00
1873	75,000 00		
1874	75,000 00	Total	625,000 00
1875	100,000 00		

As only $230,000 is required to complete the work it would be economical and prudent to take advantage of the present period, as favorable in the cost of labor and material, and end it. I therefore recommend that this sum be appropriated for the work.

The work is located in the collection-district of Port Huron, Mich.; the nearest port of entry is Port Huron; a light-house stands on the angle-crib of the breakwater.

The amount of revenue collected in this district during the last fiscal year was, in coin, $105,762.26; in currency, $25,780.72.

The whole commerce of the great chain of northern and northwestern lakes will be benefited by this work.

A sketch showing the location of this work was given in the Report of the Chief of Engineers for the year 1877.

Money statement.

July 1, 1877, amount available	$76,325 01	
Amount appropriated by act approved June 18, 1878	100,000 00	
		$176,325 01
July 1, 1878, amount expended during fiscal year		72,659 66
July 1, 1878, amount available		103,665 35
Amount (estimated) required for completion of existing project		230,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1880		230,000 00

REPORT OF MR. C. P. GILBERT, ASSISTANT ENGINEER.

SAND BEACH, MICH., *July* 1, 1878.

CAPTAIN: I have the honor to submit the following report of operations at the harbor of refuge for the past year.

Under contract of December 4, 1876, with Hemenway & Hays, of Painesville, Ohio, for continuing the work upon the breakwater, a complete superstructure was built over the 13 cribs sunk during the season of 1876, and 5 (65 feet by 38 feet) cribs were built and sunk in place at the lake end of the work, thus adding 845 linear feet to the completed portion and 325 linear feet to the length.

There were put in place under this contract 1,174,184 feet (board-measure) of timber and plank, 115,357 pounds of iron, and 3,525 cords of stone.

The contract was finished November 1, 1877, one month ahead of time.

The 5 cribs were left over winter without superstructure. They settled considerably.

Owing to the want of funds, no work has been done upon them this season.

The present dimensions of the work in place are as follows: From the north entrance to the east end, 2,730 linear feet; completed east of north entrance, 2,405 linear feet; cribs without superstructure, 325 linear feet; completed west of north entrance, 1,500 linear feet; portion of length in place, five-eighths; portion completed, six-elevenths.

The total material in place in the work is 9,152,169 feet (board-measure) of timber and plank, 770,023 pounds of iron, and 27,097 cords of stone, which amounts are, .51 of the timber and plank, .59 of the iron, and .51 of the stone required for the total length projected.

Under contract of December 8, 1876, with C. S. Barker of Sault Ste. Marie, Mich., for the removal of the wreck of the City of Buffalo and bowlder obstructions from the harbor, the removal of the wreck was accomplished by July 10, 1877, and the bowlders by July 24. Owing to a breakage of the dredge used, the contract was not completed in time. Nineteen large bowlders and the ridges of two reefs formed of bowlder stone were removed from the harbor. A portion of this latter material was used as riprap on the outside of the cribs.

During an extremely severe storm on November 9, 1877, the breakwater and its foundations sustained considerable damage.

The repair of this damage by a small force of hired labor and divers has been the work of the present season.

The excessive and irregular settlement of the cribs that were sunk during the season of 1877 indicate the necessity of preparing the foundation in advance and allowing it to settle and compact over one winter before putting the cribs upon it.

This preparation of the bottom for the cribs will for the remaining length of breakwater be an important part of the work, and being uncertain and irregular in character and material, should be undertaken by hired labor rather than through a contractor.

The complete diving outfit now available furnishes all the facilities needed for making thorough and economical work of it. I find no difficulty in either using the diving apparatus myself or in finding good men at moderate wages for the submarine work.

The dredging last season was but a commencement of a considerable amount of work much needed, and for a moderate sum expended now in this way the available area of the harbor can be enlarged to a greater extent than by the same amount in extending the pier line. The material to be removed can nearly all be used in preparing the bottom for the cribs and in riprapping those in place. I also find that underlying most if not all of these bowlder reefs and lumps is a bed of stiff clay several feet in thickness.

It is evident, therefore, that their removal will both deepen the water and leave good anchorage where there is none now. In fact, I am convinced that good anchorage can be secured in this way over the entire area of the harbor by the removal of comparatively a small amount of material.

I submit herewith a tabulated statement of the lake craft using the harbor during the year.

Very respectfully, your obedient servant,

C. P. GILBERT,
Assistant Engineer.

Capt. A. MACKENZIE,
Corps of Engineers.

Tabulated statement of lake craft using the harbor during the year ending June 30, 1878.

Time.	Direction of wind at time of entering.																								Total.
	North.			Northwest.			West.			Southwest.			South.			Southeast.			East.			Northeast.			
	Steam.	Sail.	Towed.	Steam.	Sail.	Towed.	Steam.	Sail.	Towed.	Steam.	Sail.	Towed.	Steam.	Sail.	Towed.	Steam.	Sail.	Towed.	Steam.	Sail.	Towed.	Steam.	Sail.	Towed.	
1877.																									
July	6	4	10	......	......	......	7	5	15	......	......	......	......	......	......	......	......	......	......	......	......	......	......	...	47
August	9	3	9	......	......	......	3	10	......	......	......	......	......	......	......	6	......	6	......	......	......	......	...	...	46
September	......	5	......	2	7	5	5	4	7	2	1	1	......	4	......	2	8	3	......	......	......	...	.	...	56
October	2	2	......	17	25	17	11	17	14	......	2	......	......	......	......	9	7	2	...	......	......	27	7	15	174
November	......	......	......	12	9	6	5	2	......	7	2	11	7	1	4	8	......	......	4	1	......	7	4	...	90
December	......	......	......	1	......	......	......	......	......	1	......	2	2	......	......	......	......	......	......	......	......	......	....	...	6
1878.																									
March	2	......	......	1	......	2	......	......	......	......	1	......	......	......	......	1	......	1	......	......	......	..	......	......	8
April	......	1	......	10	7	17	......	......	......	2	2	8	2	1	1	3	3	1	....	1	...	2	1	1	63
May	......	......	......	13	7	50	1	3	......	2	11	4	......	......	......	1	2	1	.	....	..	...	......	...	95
June	5	2	3	3	8	6	......	3	......	......	......	......	2	5	......	1	1	1	...	.. .	.	5	1	6	52
	24	17	22	59	63	103	32	44	36	14	19	26	13	11	5	31	21	15	4	2	....	41	13	22	
Total	63			225			112			59			29			67			6			76			637

Passages through north entrance: In, 72; out, 129; total, 201.

D D 3.

IMPROVEMENT OF DETROIT RIVER, MICHIGAN.

There was appropriated for this work by the act approved June 23, 1874, $25,000. This amount was expended during the year ending June 30, 1877.

No further appropriation was made, and during the past year no work was done. One hundred thousand dollars will be available July 1, 1878.

As soon as the requisite authority is obtained, a contract will be let and work resumed.

The work of the present season and of the year 1878–'79 will consist in blasting and removing rock and continuing the work of obtaining a channel 300 feet wide and 20 feet deep across the Lime-kiln Crossing near the mouth of the river.

In view of the great benefit that would result to the commerce of the lakes by the improvement of this point and the undoubted national importance and character of the work, I would recommend that the sum of $100,000 be appropriated by Congress at its next session for continuing the work.

The amounts appropriated for this work are as follows:

1874	$25,000 00
1878	100,000 00
Total	125,000 00

Of this amount, $25,000 has been expended. This work is located in the collection-district of Detroit, Mich. The nearest port of entry is Detroit, Mich., and the nearest light-house, Mamajuda light. The amount of revenue collected in this district during the year was, in coin, $140,413.68; in currency, $31,834.34.

The whole commerce of the great chain of lakes will be benefited very much by this work.

Money statement.

Amount appropriated by act approved June 18, 1878	$100,000 00
July 1, 1878, amount available	100,000 00
Amount (estimated) required for completion of existing project	250,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1880	100,000 00

APPENDIX E E.

ANNUAL REPORT OF MAJOR FRANKLIN HARWOOD, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1878.

UNITED STATES ENGINEER OFFICE,
Detroit, Mich., July 13, 1878.

GENERAL: I have the honor to forward herewith my annual reports for the works of river and harbor improvement under my charge during the fiscal year ending June 30, 1878.

Very respectfully, your obedient servant,

F. HARWOOD,
Major of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

E E 1.

SAINT CLAIR FLATS SHIP-CANAL, MICHIGAN.

The close of the fiscal year ending June 30, 1877, found the canal banks in a very damaged condition for reasons specified in my last annual report. On the 11th of July I opened bids for the supply of material for repairs, and subsequently entered into contract with William Lacroix, of Algonac, Mich., for the supply of turf and marsh hay, and with John A. Smith, of New Baltimore, Mich., for the supply of fascines, fagots, and barrel-stave edgings. These contracts were regularly fulfilled in the course of the season, and the material thus obtained used in the repair of the canal banks by hired labor under the superintendence of the custodian of the canal. The fascines, intermingled with marsh hay and covered by a layer of the turf, were used in repairing an extensive shallow wash on the lake face of the east bank at its southerly extremity. The fagots and barrel-stave edgings in, bundles, intermingled with the marsh hay were used on both banks to fill and stop the various caves and washes on the canal-front behind the timber revetment of both banks. Each cave and wash was made the subject of careful investigation, and the filling well rammed home and fitted as the necessities of each bit of work required. Each spot repaired was well covered with the fresh meadow turf. So thoroughly was the work done that both banks are now in excellent condition, free from all caves and washes excepting a few minor washes not needing attention and two or three caves which have since occurred at points not repaired last year, and which can be readily repaired without purchasing further material by aid of the willow clippings resulting from trimming the trees. These done up in bundles and rammed in cross-layers in the caves, then covered by a layer of earth taken from the bank at other points where its loss will work no damage, will repair the few caves that now exist and may occur during the season, at no greater expense than the hire of labor under the superintendence of the custodian. The total amount of contract material used in the repair was 40½ tons of marsh hay, 676 cubic yards of turf, 90 fascines, 216¼ cords of brush fagots, and 21,760 bundles of barrel-stave edgings; the whole costing $2,341.23.

The labor, exclusive of the custodian's salary, which is a stated stipend independent of superintendence of work, amounts to $1,262.32, making the total cost of repair in labor and material $3,603.55. Nearly all of this expenditure was incurred on account of the damages inflicted by vessels during the ice blockade of the spring of 1877.

It is gratifying in this connection to state that of the few test cases of vessels inflicting damage placed in the hands of the United States district attorney three have confessed judgment and paid the comparatively insignificant damages incidental to the confessions, thereby vindicating the law and establishing the unquestioned control of the United States over the navigation of this canal at slight cost to the involuntary trespassers, but to the great advantage of the general interests of commerce.

Two cases yet remain in abeyance, but, as the testimony is of the same positive nature as in the case of those who have compromised, there is no doubt that the law in the case of this canal is completely vindicated. The practical results at the canal are still more gratifying. The authority of the custodian, heretofore in many cases a *brutum fulmen*, is recognized by all vessel masters, and the immunity of the banks from willful damage is fully secured.

The custodian of the canal is paid a stated salary of $5 per day, Sundays excepted, by direct order of a former Secretary of War. As his service (which is a very responsible one) extends throughout the whole year, from day to day and through all days, I respectfully request that he may be placed on a stated annual or monthly salary, such as may be considered a proper equivalent for the services he renders. The total of his present compensation amounts to $1,565 per annum.

On account of the exhaustion of the balance of old appropriation of 1873 before the close of the fiscal year, by reason of the extraordinary drain on it for repairs of canal banks, there is still due the custodian on last year's salary, for the months of January, 1878, to June, 1878, inclusive, $775, which is noted in the money statement as an outstanding liability.

While the canal banks are now in very good condition, the four pier-heads have been neglected for several years, and need various minor repairs in filling by bundles of barrel-stave edging where the filling originally placed has in process of time washed out; and also about 50 piles have to be driven and secured to give adequate protection against abrasion of the pier-heads by running ice.

For this purpose, and for the payment of the custodian's salary and other incidental expenses of office-work and minor repairs, an appropriation of $3,000 will be needed in addition to the one already granted for the year 1878–'79.

This work is located in the collection-district of Detroit, Mich. The nearest port of entry is Detroit, Mich., but this has no especial bearing on the commercial importance of the work, as the whole commerce of the great lakes is benefited by its existence, and the revenue of every custom-house on the lakes incidentally increased by the facilities it offers as an important cut-off in the great thoroughfare from Lake Erie to Lake Huron.

For revenue statistics therefor see general reports of lake custom-houses.

There are two light-houses on the canal banks.

Money statement.

July 1, 1877, amount available	$5,883 98	
Amount appropriated by act approved June 18, 1878	5,000 00	
		$10,883 98
July 1, 1878, amount expended during fiscal year	5,883 98	
July 1, 1878, outstanding liabilities	775 00	
		6,658 98
July 1, 1878, amount available		4,225 00
Amount (estimated) required for completion of existing project		$3,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1880		3,000 00

Abstract of bids for supply of repair-material for Saint Clair Flats Canal, Michigan, opened July 11, 1877.

No. of bid.	Name of bidder.	Residence.	Fagots, per cord.	Fascines.	Turf, per cubic yard.	Hay, per ton.	Edgings, per bundle.	Date of delivery.
1	William Lacroix	Algonac, Mich			$0 63	$7 00		
2	John A. Smith	New Baltimore, Mich	$3 50	$1 25	75	9 50	$0 03¼	July 18 to Sept. 24.
3	William Lacroix	Clay, Mich			63	7 00		July 20 to Sept. 1.
4	Washington Moore	do				*150 00		Aug. 1 to Sept. 1.
5	John K. Harrow	do	3 75	2 40	70	6 00	05	July 25 to Sept. 25.
6	Charles W. Danger	Port Huron, Mich					†2 90	July 22 to Sept. 22.
7	Hubert Brossart	Detroit, Mich	6 75	99	1 75	9 75	09¼	Aug. 1 to Sept. 1.

* Total supply. † Per cord.

Abstract of contracts.

Contract of John A. Smith, of New Baltimore, Mich., for supplying fascines, fagots, and barrel-stave edgings, dated August 14, 1877, expired October 18, 1877.

Contract with William Lacroix, of Algonac, Mich., for supplying turf and marsh hay, dated August 3, 1877, expired October 1, 1877.

Abstract of contract for each class of material and labor.

Fagots, per cord (128 cubic feet)	$3 50
Fascines, each	1 25
Turf, per cubic yard	63
Hay, per ton	7 00
Edgings, per bundle	03¼

E E 2.

IMPROVEMENT OF SAINT CLAIR RIVER AT THE MOUTH OF BLACK RIVER, MICHIGAN.

This work was transferred to my charge by instructions of Chief of Engineers, dated April 22, 1878. At that time no appropriation was available for the improvement. Since then, by act of Congress approved June 18, 1878, $1,500 has been appropriated to complete the removal of the shoal at the mouth of Black River. It is well out in the Saint Clair River, consists mainly of gravel, and probably has not changed materially since work was abandoned for lack of funds, September 30, 1876.

I propose to devote a portion of the present appropriation to ascertaining the actual present condition of the shoal, and if I find that its removal can be completed by aid of the remainder, I propose to so complete the work by hired labor and machinery, the small expenditure involved not warranting the ordinary course of advertising and making contract. If, however, it shall appear that the balance of appropriation is inadequate to complete the removal of the shoal, I propose to reserve the balance and make additional estimate for completion of the work, and when this estimate shall have been honored in full, to undertake the complete removal of the shoal.

The original estimate made for this work by Maj. O. M. Poe, in his report dated July 21, 1871, was 168,300 cubic yards of dredging, at 40 cents per cubic yard, $67,320.

The amounts appropriated for it have been as follows:

1872	$15,000 00
1873	15,000 00
1874	15,000 00
1875	10,000 00
1878	1,500 00
	56,500 00

All of which has been expended, excepting $1,500, which has just become available.

Nearly the whole commerce of the northern and northwestern lakes passing here has been and will be benefited by this improvement.

It is located in the collection district of Huron, Mich.; the nearest port of entry being Port Huron, and the nearest light-house at Fort Gratiot, Mich., in the immediate vicinity.

Money statement.

Amount appropriated by act approved June 18, 1878	$1,500 00
July 1, 1878, amount available	1,500 00
Amount (estimated) required for completion of existing project	1,500 00

Statement exhibiting the amount of business transactions in the district of Huron, through the port of Port Huron, during the fiscal year ending June 30, 1878.

Classification.	Fiscal year ending June 30, 1878.
Value of imports entered for transportation to interior ports	$169,026 00
Value of imports entered for transportation and exportation to Red River settlement	404,868 00
Value of imports entered for consumption	424,291 00
Value of exports of growth and production of United States to adjacent British provinces	6,645,004 00
Amount of duties collected, in coin	105,762 36
Amount of duties on merchandise entered for transportation to interior ports	57,943 51
Amount of duties on merchandise entered for transportation and exportation to Red River settlement	265,640 81
Amount of official fees collected, currency	14,697 91
Amount of tonnage tax, currency	3,358 46
Amount of marine hospital collections, currency	2,922 86
Amount of inspection fees of steamboats, currency	2,264 35
Amount of licenses of pilots and engineers	2,290 00
Value of free goods imported into the district of Huron	571,531 00
Amount received from fines, penalties, and forfeitures	380 34
Amount received from bonding seals	886 80
Number of entries made of all kinds	6,188 00
Number of entrances and clearances of vessels	8,737 00
Number of transportation bonds made	173 00
Number of transportation and exportation bonds made	698 00
Amount of tonnage outstanding owned in district	53,668 81
Number of vessels owned in district	350 00
Number of immigrants arrived at this port	30,610 00

JOHN P. SANBORN, *Collector.*

CUSTOM-HOUSE, PORT HURON,
Collector's Office, July 10, 1878.

E E 3.

IMPROVEMENT OF AU SABLE RIVER HARBOR, LAKE HURON, MICHIGAN.

The charge of this work was transferred to me by Maj. Godfrey Weitzel, Corps of Engineers, April 27, 1878, in accordance with the Chief of Engineers' instructions of April 22, 1878. In order to fully satisfy myself as to the state of affairs by personal inspection, I visited the harbor, and found it in substantially the same condition as reported to Major Weitzel by Captain Lee in the terms recited in his last annual report.

The harbor and river fronts are, with the exception of the river-front proper of the town of Au Sable, completely taken possession of and monopolized by the mill-owners. But while I find the facts of the case this year the same as reported by Captain Lee last year, I can by no means concur in all his conclusions either as to cause or effects. The encroachments on the river banks within the town limits of Oscoda have, in my opinion, been a benefit rather than a detriment to the harbor, and the incomplete attempt at confining the river to 100 feet in width has, wherever it has been carried into effect, resulted in deepening the channel. This is most natural, as the soil is light sand, and the scour, superinduced by a restricted channel, naturally deepens the water. While the general attempts of the local mill-owners to improve their river-fronts have been, in my opinion, harmless, some particular acts have, no doubt, materially damaged the improvements effected by the United States in years gone by.

For instance, the cut-off canal made through a neck of land above the village of Oscoda, without doubt, at the time of its construction sent large volumes of sand down to be deposited in Au Sable Harbor. But on the other hand, the general result has been rather in the interest of the preservation of the harbor, as the cut-off, having reached its normal condition, sends down now the natural drift from one sand bank, while it cuts off from the current-action several banks through a long reach of winding channel which would otherwise be, each one of them, a source of sand deposit. Again, the river has been tapped near the Oscoda bridge, and part of the current diverted to feed a boom-canal belonging to a mill at the mouth of the river. This detracts from the natural scour of the river and should be regulated. On the river front of the same owner, piles have been driven well out in the river bed. These should be removed before any further improvement is undertaken. In a word, I concur entirely in the general conclusion of Major Weitzel and the policy advocated by him, with regard to the improvement of the harbor, so far as relates to refraining from further improvement as long as the United States is debarred from the free control of the locality proposed to be improved. But in this connection I must state that I found on my late visit to Au Sable the owners of river-fronts, both in Au Sable and Oscoda, uniformly disposed to concede all necessary jurisdiction to the United States, and in one case, at least, prepared to rectify their water-front in such manner as might be prescribed by the United States authorities.

I therefore cannot concur wholly in the position assumed by my predecessor in regard to this work, but considering the reasonable disposition evinced by some of the mill-owners, am of the opinion that the improvement may be profitably resumed whenever the property-owners along the river and harbor fronts are willing to give suitable guarantee to the United States of non-interference in the government improvements, and cession of all necessary jurisdiction over their respective water-fronts for purposes of improvement. In its present condition, the harbor is a wreck and a discredit to the government. At an expenditure small in comparison with the resulting increase of commerce, the piers could be repaired, and navigation, with 10 feet depth of water and 100 feet width of channel, opened up to the several Oscoda mills, thereby renewing the life of the harbor and increasing the revenue receipts to an extent hardly to be estimated under existing circumstances. At present, vessels drawing not more than 8 feet of water can get into the river to the piers, but when there they only reach one mill, while several mills above are entirely cut off from river-navigation by a shoal within the town limits of Au Sable, readily removed at a slight expense. Above this shoal, on the Oscoda River front, there is full 10 feet depth of water in the channel. In my opinion, the channel, if confined to a uniform width of 100 feet, would soon, by its own current, scour out to a uniform depth of 10 feet clear to the mouth of the harbor, and with a slight aid in dredging the bar and removing the river obstacles in Au Sable, Oscoda could be added to the harbor of Au Sable, and a new commercial life infused into both places. Of course, a careful examination of the river near its mouth should be made, and a comprehensive project, comprising within its scope the river-reaches of both Au Sable and Oscoda, should be prepared before any further improvement is made. The piers also need repairs very badly, but under the present circumstances I am not prepared to recommend any appropriation.

In conclusion, therefore, I respectfully recommend that the harbor be abandoned until such time as all the owners of river fronts shall be prepared and give evidence of their sincerity by ceding the necessary jurisdiction to the United States for purposes of improvement, or until, by general law, the United States shall be in position to assume such jurisdiction. When that time arrives, in my opinion the harbor can be improved to the advantage of the United States in matter of revenue, by adopting a comprehensive scheme after careful examination into the possibilities of the case. Until that time no further appropriation is desired.

Au Sable River Harbor is situated in the Huron collection-district, Michigan, about 14 miles north of Tawas light-house. The nearest port of entry is Port Huron, Mich.

Money statement.

July 1, 1877, amount available	$2,113 49
July 1, 1878, amount expended during fiscal year	1,493 38
July 1, 1878, amount available	620 11

COMMERCIAL STATISTICS.

OFFICE OF DEPUTY COLLECTOR OF CUSTOMS,
Au Sable, Mich., *July* 10, 1878.

Report of business transacted at this office for the fiscal year ending June 30, 1878:

Number of vessels entered and cleared	27
Total tonnage	44,198
Total number of runs	1,515
Total receipts of office	$631 65

In addition to the above is a daily line of steamers running between Bay City and Alpena and touching at this port, which amounts to an annual tonnage of 156,000; also 3 steamers plying weekly between Detroit and Mackinaw and touching at this port, which amounts to an annual tonnage of 108,000; also 12 vessels loaded here, which had cleared from Detroit for Chicago direct, tonnage 3,700; making a total annual tonnage doing business at this port of 311,898, which will be increased during some years to come, as the lumber and salt manufacturing establishments are annually increasing.

Respectfully submitted.

JNO. W. GLENNIE,
Deputy Collector of Customs.

E E 4.

IMPROVEMENT OF SAGINAW RIVER, MICHIGAN.

During the working-season of 1877, the appropriation of 1876 was expended under contract with Harvey S. Dale, of Chicago, in completing as far as possible the river revetment at Carrollton Bar. The bulkhead at Hoyt's mill-site cutting off the flow of water behind, the revetment was constructed and 500 linear feet of completed revetment was added to the northerly end of the work. At this stage of the year's operation it became evident that while the balance of appropriation would not suffice to complete the Carrollton Bar project, the connection with the firm river-bank at the lower end could still be made by a section of incomplete work, carrying out the construction only as far as necessary to secure the incomplete section from damage during the period intervening before further appropriation should become available. The desirability of this measure was apparent, as it is readily seen that only after the entire Carrollton Bar project is completed the full effect of the revetment in establishing and maintaining the Carrollton Channel can be expected to be attained. To the 500 feet of complete work, therefore, I added 330 linear feet of unfinished work secured to the extent above specified, by this means reaching the firm river-bank, at which point an arm 115 feet long, similarly incomplete, was run back into the shore. At the same time sufficient dredging was done to complete the Carrollton Channel to a width of 90 feet with nearly 10 feet depth. It was expected that the Carrollton revetment being thus closed in at both ends, the scour designed to be effected in the channel by means of its intervention and guidance would materially improve the depth and possibly increase the width of the channel. Unfortunately, however, the winter of 1877–'78 was an extremely open one, and as a consequence was not followed by spring freshets of any magnitude. The work can therefore be hardly said to have had a fair test. Sufficient scouring has, however, taken place to indicate that the work will eventually effect the end for which it was designed, and that the Carrollton Channel once fully opened, will maintain itself by the natural scour and the constant passing of heavy-draught vessels during the season of navigation. I, however, propose, by aid of the appropriation afforded by act of Congress approved June 18, 1878, to dredge the channel to a full width of 100 feet and a full depth of 10 feet, which is all that can be readily maintained, and all that the necessities of commerce require.

On the 4th of October, 1877, a spark from a passing steamer set fire to and destroyed to within 2 feet of the water-level 200 linear feet of the work of 1876, at the northerly end of the longer section. This I propose to repair by fitting over the burnt section a timber-deck, making the height of the section thus repaired 3 feet above mean low-water. The section at this reduced height will serve as an auxiliary waste-wier in times of freshet, when the bayou which debouches back of the work pours out large volumes of flood water through the gap in the revetment, now only 50 feet in width. This gap is a necessary evil under existing circumstances, and tends in time of flood to create a bar in the main channel in its vicinity, but this action will be materially checked in very high water by the additional vent afforded by the low section of work at its southerly border. Thus economy in repair, resulting from the reduced height of the burnt section, can be attained without detriment to the general efficiency of the work, but rather adding to that efficiency in time of high-water.

In order to obviate as far as possible the danger of fire again catching in the work from the sparks of passing steam-vessels, it is also proposed to sheath the entire river-face with plank set close together from the top of the work to the water-level. This measure of improvement, the repair of the burnt section, the completion of the unfinished work of last year, a general overhauling and refilling of work of past years in which the filling has settled, and the completion of the dredging of the Carrollton Channel, will constitute the work of the present season at Carrollton Bar, and will complete that project at a probable cost of $8,000. This it is proposed to do by contract for labor and material after due course of advertising, completing the work in the course of the present working-season.

In like manner it is also proposed to begin the work of improvement at Zilwaukee Bar, about a mile farther down the river, by building a wing-dam at the head of Crow Island, of construction similar to the Carrollton Bar revetment. This dam, 900 feet long and 6 feet in height above low-water, will be so located as to deflect the current fully into the Zilwaukee Channel and create a scour, which it is hoped during the winter of 1878–'79 and the ensuing spring will establish the trace of a well-defined channel through the present Zilwaukee Bar. Subsequent dredging will complete the improvement at this reach of the river. In order to attain the object above noted, it is proposed to finish this dam during the present working-season, at a probable cost of $4,000.

About half of the appropriation of 1878 will then remain unexpended. Before it can be expended to advantage, examination of the river at New York works and other points where shoal water is known to exist will be necessary, in order to prepare intelligent projects for further improvement. This will be done during the year 1878–'79, and during 1879 it is expected to expend the balance of appropriation profitably in securing a good channel at New York works and other points below, as far as the appropriation will permit.

Before any further measures of improvement beyond the projects of the present season are undertaken, it is very important that the matter of jurisdiction over boomage, referred to in my letter of December 3, 1877, be settled, and that the United States should have control over the river in the region of proposed improvement, so far as necessary to prevent the partial or entire nullification of the improvement. It is not necessary for me to repeat in this report the details furnished in my memoir of December 3, 1877, on this subject. I simply refer to it in obedience to the instructions sent me in answer to that memoir, and trust that the general action already taken by the Chief of Engineers in regard to the subject of jurisdiction and control at regions of improvement will bear such fruit during the present year that the whole matter will be settled before I shall have occasion to bring it up again.

The cases of the two booms having direct relation to the projects of the present season on account of their vicinity are not very material, and can well be held in abeyance until a general sentiment of the question is obtained. A preliminary survey of Zilwaukee Bar develops the fact that Rust, Eaton & Co.'s boom, while it occupies the very border of the channel proposed to be obtained, does not actually infringe upon its limits; and I have the assurance of Mr. Rust, of the firm, that no piles will be driven beyond its present limit. Under the circumstances, therefore, I see no objection to the Zilwaukee improvement going on without further reference to this matter.

Under date of February 7, 1878, I received instructions to make an early and detailed report upon the subject-matter of the preamble and resolutions of the House of Representatives, dated February 5, 1878, relating to the proposed construction of a bridge across the Saginaw River within the limits of the city of East Saginaw. My report was forwarded on the 20th of the same month, giving full information on the points desired. Since then construction of the bridge in question has begun, and at this date the piers and abutments are completed, and the superstructure is in process of building.

In my opinion, it will not add materially to the present impediments to navigation at East Saginaw offered by structures of the same character, some of them more unfavorably located.

Saginaw River improvement is located in the Huron collection-district, Michigan. The nearest light-house is at the mouth of the river. The nearest port of entry is Port Huron, Mich.

The original estimate for this work was $56,000, the whole amount of which has been appropriated, as follows:

1874	$15,000
1875	30,000
1876	11,000
	56,000

To which add $50,000, estimated in my last annual report, for the reasons given in the report for the year preceding. Of this $25,000, has been appropriated by act approved June 18, 1878; $25,000 is still required to complete the existing project.

Money statement.

July 1, 1878, amount available	$10,402 01	
Amount appropriated by act approved June 18, 1878	25,000 00	
		$35,402 01
July 1, 1878, amount expended during fiscal year		10,402 01
July 1, 1878, amount available		25,000 00
Amount (estimated) required for completion of existing project		25,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1880.		25,000 00

Abstract of contract.

Contract with Harvey S. Dale, of Chicago, for furnishing material and labor for extension of pier, revetment, and dredging, dated April 21, 1877, to expire September 1, 1877.

Abstract of contract for each class of material and labor:

1. Pine timber framed and put in place, per M feet, board-measure	$18 00
2. Oak and Norway pine piles, and driving, per linear foot	14
3. Drift-bolts, screw-bolts, and washers, per pound	04½
4. Slabs in place, per cord	1 10
5. Stone in place, per cord	7 00
6. Dredging, per cubic yard	35

COMMERCIAL STATISTICS.

CUSTOM-HOUSE, EAST SAGINAW, MICH.,
Deputy Collector's Office, July 11, ——.

DEAR SIR: In compliance with yours of the 8th instant, I hand you statistics for the port of East Saginaw, Mich., for the fiscal year ending June 30, 1878, which show a large increase of fees collected over last year's business.

My remarks to you, contained in mine of a year ago, will apply to the business of the port for the past year, relative to cargoes shipped on through clearances, and also to cargoes shipped at this end of the river, where clearances have been obtained at the port of Bay City.

Very truly, yours,

A. FERGUSON,
Deputy Collector.

B. H. MUEHLE, Esq.,
United States Inspector Saginaw River Improvement.

Summary statement of vessels in the coasting trade that have entered and cleared from the port of East Saginaw, Mich., showing the tonnage of the same, and fees collected, for the fiscal year ending June 30, 1878.

Months.	Entered.	Tonnage.	Cleared.	Tonnage.	Fees.	Remarks.
July, 1877	80	25,048	75	22,234	$170 02	No duties collected
August, 1877	97	30,117	97	28,506	167 40	Do.
September, 1877	115	34,109	106	30,803	302 50	Do.
October, 1877	92	26,577	79	23,177	230 71	Do.
November, 1877	94	29,278	81	24,636	105 70	Do.
April, 1878	43	14,381	58	17,501	211 39	Do.
May, 1878	110	34,541	112	35,053	209 70	Do.
June, 1878	70	20,273	62	19,716	386 52	Do.
Total	701	214,324	670	201,806	1,784 03	
Fees received for year 1877					791 75	
Increase for the year					992 28	Currency.
Less, gold					263 35	Gold.
					728 93	

All of which is respectfully submitted.
East Saginaw, July 11, 1878.

A. FERGUSON,
Deputy Collector of Customs.

B. H. MUEHLE,
United States Inspector Saginaw River Improvement.

SURVEY OF CARROLLTON BAR, SAGINAW RIVER, MICHIGAN.

UNITED STATES ENGINEER OFFICE,
Detroit, Mich., January 10, 1878.

GENERAL: I have the honor to forward herewith on roll a tracing of the inspector's survey of Carrollton Bar (Saginaw River) and the government improvements in the vicinity, which survey was made at the close of the season's operations of 1877. It will be seen from this map that while a good channel of over 9 feet water, low stage, exists continuously along the front of the United States revetment, the desired depth of 10 feet has not been continuously attained. It was attained along the area dredged in 1877, which is indicated by the close soundings, but the bed being of light shifting sand, and a heavy gale of wind veering to the northwest, accompanied by an up-current of the river, followed by slack-water, having arisen shortly after the close of the dredging and before the soundings were taken for this survey, a portion of the light sand of Carrollton Bar was washed over by the northwest wind into the newly-dredged area, thus slightly shoaling it up, in which condition it will probably stay until the spring freshet of 1878.

In my opinion there has as yet been no fair opportunity given for the beneficial effect of the United States revetment upon the adjacent channel to be shown, owing to the absence heretofore of any bulkhead at the head of the revetment to shut off the scouring action behind it and confine it to the channel sought to be improved. This bulkhead, however, which was only completed at the close of the working season of 1877, being now interposed, I confidently look for a material scouring and consequent deepening of the Carrollton Bar Channel, by the freshet of the spring of 1878, which will, by the interposition of the bulkhead, be mainly confined in its scouring action to the river-channel proper, and, naturally following the concave front of the revetment, tend to increase uniformly the depth of water along that front. At any rate, whatever beneficial result is to be attained from this scouring effect will have developed itself after the subsidence of the spring freshet of 1878, and it is therefore not safe to project any further measure of improvement at Carrollton Bar upon the basis of the data furnished by the survey of 1877, but rather upon comparison of the soundings of this survey with soundings taken over the same area after the freshet of the spring of 1878 shall have subsided. It is hoped that the result of this comparison will be to demonstrate that no further dredging will be needed along the revetment, and that consequently the improvement in the vicinity of Carrollton Bar, excepting the finishing of the incomplete work of 1877, may be considered completed.

There exists, however, abreast of surveying station B, the most serious obstacle to navigation along the whole Carrollton front, in the presence of a swale over which there is at some points but little over 9 feet soundings at low stage. This swale has been bitterly complained of to me during the working season of 1877, deeply-loaded vessels constantly touching upon it, but I did not put the dredge at work at it, partly for lack of available funds, the entire appropriation being needed to secure other more important objects, and partly because I hoped that it would be scoured away by the freshet of the spring of 1878, which I expected to bring to bear on it in full force as a result of the interposition of the bulkhead now for the first time, as a part of the work of 1877, brought into play to effect this désirable object. It is, however, possible that, after all, this shoal may have to be dredged through to get the desired 10 feet depth of water at low stage, and, if so, this will be the first and most important measure of improvement to be undertaken in 1878. But as this and like contingencies depend entirely upon the development of the spring of 1878, after the effect of the bulkhead upon the scour of the current on the channel shall have become apparent, the survey herewith respectfully submitted, however complete and full in its details as to the state of the channel and work at the close of the working season of 1877, is rather to be considered in the light of a preliminary survey—a basis of comparison to which further examination being referred, the changes in soundings which may then become apparent will readily suggest to the engineer in charge of the work such measures of improvement, if any, as may be necessary to complete the improvement at Carrollton Bar.

I am, general, very respectfully, your obedient servant,

F. HARWOOD,
Major of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

E E 5.

IMPROVEMENT OF ALPENA HARBOR, AT MOUTH OF THUNDER BAY RIVER, MICHIGAN.

Work on this harbor was finished and closed by Major Weitzel before its transfer to me on the 27th day of April, 1878. It is now a complete harbor in every respect, and no further appropriation is needed.

It is situated in the Port Huron collection district. The nearest port of entry is Port Huron, Mich. The nearest light-house is at the mouth of Thunder Bay River.

Money statement.

July 1, 1877, amount available	$4,500 00
July 1, 1878, amount expended during fiscal year	3,935 36
July 1, 1878, amount available	564 64

Statement of entrances and clearances and tonnage of vessels and fees collected at Alpena during the fiscal year ending June 30, 1878.

Month.	Entrances.		Clearances.		Tonnage.	Fees collected.
	Over 50 tons.	Under 50 tons.	Over 50 tons.	Under 50 tons.		
July	70	....	74	....	22,711	$157 42
August	65	2	67	....	15,368	114 43
September	75	....	77	1	22,127	161 85
October	64	....	62	....	20,384	143 65
November	54	1	60	....	19,917	46 55
December*	....	....	....	....	....	....
January*	....	....	....	....	....	....
February*	....	....	....	....	....	....
March	14	4	13	....	6,429	7 30
April	45	....	50	3	10,623	38 15
May	52	....	55	....	14,567	36 40
June	62	....	61	....	15,310	45 30
Total	501	7	519	4	147,436	749 35

* No transactions.

COLLECTOR'S OFFICE,
Port Huron, July 12, 1878.

JOHN P. SANOBRN,
Collector.

Abstract of proposals for dredging at Thunder Bay River Harbor, opened July 7, 1877.

Names.	Residence.	Price per cubic yard.
Thomas M. Hubbell	East Saginaw, Mich	$0 17
Williams & Upton	Houghton, Mich	19
Roys J. Cram	Goderich, Ontario	22

Abstract of contract.

Contract with Thomas M. Hubbell, of East Saginaw, Mich., dated July 23, 1877, closed October 31, 1877, for dredging at Thunder Bay River Harbor, 17 cents per cubic yard, scow measurement.

E E 6.

IMPROVEMENT OF CHEBOYGAN HARBOR, MICHIGAN.

By the use of two dredges hired under contract with Carkin, Stickney & Cram, of East Saginaw, Mich., I succeeded during the fall of 1877 in completing the project set forth in my last annual report. At the close of the season's dredging, on the 18th of November, 58,510 cubic yards of excavation had been effected, securing a channel of 150 feet in width, with an average depth of clear 13 feet below low-water level. By cutting away the east bank of the Cheboygan River, opposite the steamboat landing, over 200 feet in width of channel with clear 13 feet in depth was obtained, thereby enabling propellers of the larger class to enter and leave the harbor, turning at the dock, whereas heretofore they had been obliged to back out into the lake. Owing to the great inconvenience attending this movement, but one propeller of this class frequented the harbor at all. Now the harbor is readily accessible to them, and is being more freely used. The channel, varying in width from 150 feet at its mouth to over 200 feet abreast of the steamboat landings, has not shoaled materially during the winter, but has maintained its depth excellently. At a late visit, I myself witnessed the arrival and departure of the Fountain City, a propeller 222 feet in length, loaded to over 12 feet draught. She entered the channel without difficulty, passed its entire length without grounding, made her landing, turned readily at her dock, and left the harbor, all within the course of an hour. Her master expressed himself entirely satisfied with the facilities of the harbor for his class of vessel. Her sister propeller, the Badger State, now makes her landings at Cheboygan, which she has never previously done, and there is no difficulty in the way of any propeller not exceeding in length 225 feet or drawing more than 12½ feet entering and leaving at will.

My requisition for $20,000 to complete this improvement was honored only to the extent of $8,000 in the appropriation bill approved June 18, 1878. This sum will suffice probably to add another dredge-cut of 25 feet to present width of channel, making it 175 feet wide from river to lake, with clear 13 feet depth of water. This I propose to do during the present working season by contract labor, after due course of advertising.

An additional appropriation of $12,000 is asked to complete the project, probably leaving a small balance as a fund upon which to draw for the removal of incidental obstructions, such as sunken logs, which will from time to time ground in the channel and form the nucleus for a bar if not removed. Such an obstruction is now reported just outside of the entrance of the present channel, and directly in the way of vessels entering. It is proposed to remove this obstacle, whatever it may be, in the course of the present season's work.

The original estimate of the cost of this work is $395,000, which was made by Maj. F. U. Farquhar, Corps of Engineers, in 1871. The amounts that have thus far been appropriated for this work are as follows:

1871	$10,000	1875	15,000
1872	15,000	1876	10,000
1873	15,000		
1874	15,000	Total	80,000

all of which has been expended on the work, which is located in the Superior collection-district, Michigan. The nearest port of entry is Marquette, Mich. The nearest light-house is Cheboygan light.

Number of entrances and clearances at the port of Cheboygan, Mich., from July 1, 1877, to June 30, 1878, as taken from the records of the custom-house:

Entered, 165; tonnage, 42,940.

Cleared, 412; tonnage, 126,609.

The clearances include crafts from Canadian ports which reported, bound up, during the year.

From the receiving-books at the two docks is taken the following:

For the above period there arrived and departed from this port 284 steamers, with a tonnage of 150,046.

The Marine City, Robert Holland, Saint Joseph, and Saint Paul, which aggregated 89 trips, are only credited once, while in reality, in nearly every instance, they were in twice each trip.

In addition to the above, there has been quite a number of vessels which have loaded here that have had through clearances, and consequently no record of their tonnage and entrance and clearance kept. This would increase the amount of tonnage for the season a very considerable amount.

Total amount received at this port during the year, including amounts collected for tonnage-tax, $2,435.04.

Money statement.

July 1, 1877, amount available	$9,920 77	
Amount appropriated by act approved June 18, 1878	8,000 00	
		$17,920 77
July 1, 1878, amount expended during fiscal year		9,920 77
July 1, 1878, amount available		8,000 00
Amount (estimated) required for completion of existing project		12,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1880		12,000 00

APPENDIX F F.

ANNUAL REPORT OF LIEUTENANT-COLONEL N. MICHLER, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1878.

UNITED STATES ENGINEER OFFICE,
Toledo, Ohio, July 13, 1878.

GENERAL: I have the honor to transmit herewith the annual reports upon the various works of harbor improvement under my charge for the fiscal year ending June 30, 1878.

Very respectfully, your obedient servant,

N. MICHLER,
Lieut. Col. of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

F F 1.

IMPROVEMENT OF MONROE HARBOR, MICHIGAN.

As described in previous engineer reports this harbor is not a natural one, but an artificial one has been formed by the construction of wooden piers out from the lake shore at a point 1½ miles to the northward of the mouth of the Raisin River. The latter is a small sluggish stream, without any appreciable current. As it approaches the lake it courses through low marshes covered with grass and reeds. The piers first run parallel and 100 feet apart for a portion of their length, and then gradually spread out for a short distance until a depth of 10 feet is obtained at ordinary stage of low-water in the lake. The north pier is 1,350 feet long, and the south 925 feet. This harbor, so designated as such, is connected with the river 1½ miles above its mouth and at its junction with Little Sandy Creek by a direct channel-way or cut made on its prolongation, known as the United States Ship Canal. About 3,200 feet by the bed of the stream above the head of the latter canal a second one is entered; this one is named the Monroe City Canal, built at the expense of the city for the purpose of straightening and shortening the water-course by cutting off one of the beds of the river. By these water communications the distance from Monroe to the lake shore is about 3½ miles.

The dimensions of the canals are as follows: The Monroe City: length, 1,300 feet; width, 100 feet; depth, 11 feet. The United States: length, 4,650 feet; width, 100 feet; depth, 11 feet. The artificial harbor, with its piers and bulkheads, and the two canals with their revetted sides, constitute the nature of the plan of improvement adopted for Monroe Harbor. The work was commenced during the year 1835, but information as to its original estimated cost is not accessible at present. The several appropriations have been applied in the following manner: During the first few years the work was prosecuted by digging out the cuts or canals by pick and shovel and subsequently by the more improved methods of dredging; their sides were then protected by revetments of sheet piling; in connection with these improvements the piers and pier-heads which project from the shore-line into the lake were constructed. During the last few years the work has been principally confined to the renewal of the revetments of the two canals, wherever damaged or destroyed, together with the repairing and strengthening of the outer piers. Some dredging has been necessary to maintain the proper depth throughout the channel.

The appropriation for the fiscal year just closed, amounting to $5,000, has been applied during the actual working season from June to September, both inclusive, of the year 1877 as follows: To renewing 1,425 linear feet of revetment, and thereby filling up the gap on the south side of the United States Ship Canal, also 100 feet on the north side; and by the extension of the revetment on the north side from the mouth of Little Sandy Creek to the terminus of the section finished in 1875, a distance of 380 feet; a total of 1,905 feet. Some needed small repairs were made to the piers. In many places the piles and sheeting were found to be badly rotted away, or broken off to the water's edge, by exposure to the atmosphere or in consequence of damage incurred by heavy storms and the crushing of accumulated ice at the opening of spring navigation.

The following is the bill of material furnished and put in place during the year:

3,047 linear feet of oak piles.
126,116 feet (board measure) of oak timber and plank.
3,975 pounds of bolts, nuts, and screws and washers.
1,155 pounds wrought spikes.

The work has been executed by the purchase of the material in open market and by day-labor. There still remains to be completed about 1,500 feet of renewed revetment on the side of the United States Ship Canal, and 1,750 feet of the Monroe City Canal. The north and south piers will also have to be repaired at times, as they are subject to damages caused by the frequent storms. Although careful soundings throughout the channel, made during the last working season, indicated no decrease of depth of water, still the canals between the revetments, as well as the bar or shoal which usually forms outside of the entrance or pier-heads, will require dredging at times in order to preserve the proper depth. The renewal of those parts of the revetments of the two canals which still require it will render them complete in all their parts, and they will remain, in all probability, in good condition for several years to come. No full estimate for a permanent improvement can be made, as the works will always be exposed in a more or less degree to damage arising from the decay and destruction of the timbers from general exposure to the weather, and particularly from the crushing effect of ice and storms.

The estimated cost of placing this work of improvement in thorough order, and in such condition as not to require any extensive repairs for several years to come, is $7,500 in addition to the sum appropriated for the present fiscal year. The last appropriation, made in 1876, is exhausted.

The following table shows the amount appropriated for this work of harbor improvement up to and including the fiscal year ending June 30, 1879:

1835	$30,000 00	1872	$10,000 00
1836	15,000 00	1873	15,000 00
1837	30,000 00	1874	10,000 00
1838	15,000 00	1875	10,000 00
1844	20,000 00	1876	5,000 00
1852	14,000 00	1878	2,500 00
1866	31,015 27		
		Total	207,515 27

To what extent the general commerce of the country will be promoted by this particular work of improvement, attention having been invited to the matter in connection with the several works of improvement by the "Joint resolution in relation to surveys and examinations of rivers and harbors," approved July 27, 1868, can only be surmised by an examination of the list of entrances and clearances at this port during the last several years. By that there does not appear to be any immediate prospect of an increase of tonnage. It will be seen that the latter is not very large. Nor is the harbor one that is well located; neither is it much used as a refuge from storms for vessels engaged in the navigation of the lakes.

There is a light-house on the north pier-head, at the outer entrance to the harbor and the United States Ship Canal. The light is a fixed white of the fourth order. The nearest defensive work is Fort Wayne, a short distance below Detroit; it is distant about 30 miles. The principal scource of supply is by the lake. The terminus of the line from Chicago and Adrian was formerly at the entrance of the harbor.

Monroe Harbor is in the collection-district of Detroit, Mich. The amount of revenue collected during the fiscal year ending June 30, 1878, was $25.74, coin and currency.

Entrances and clearances during the fiscal year ending June 30, 1878: Number of vessels, 64; tonnage of same, 5,327 tons.

Money statement.

July 1, 1877, amount available	$4,492 44	
Amount appropriated by act approved June 18, 1878	2,500 00	
		$6,992 44
July 1, 1878, amount expended during fiscal year	4,481 74	
July 1, 1878, outstanding liabilities	10 70	
		4,492 44
July 1, 1878, amount available		2,500 00
Amount (estimated) required for completion of existing project		7,500 00
Amount that can be profitably expended in fiscal year ending June 30, 1880.		7,500 00

F F 2.

IMPROVEMENT OF TOLEDO HARBOR, OHIO.

As already presented in the last annual report, the following is a condensed history of the several successive stages followed in the prosecution of this work:

The original plan for the improvement of the harbor consisted in widening and deepening the several reaches of the southwest channel through Maumee Bay, connecting the waters of the river of the same name, upon which the city of Toledo is built, with those of Lake Erie. The depth deemed sufficient for the purposes of navigation at that time was

14 feet at mean low-water in the lake, and the breadth throughout the passage 120 feet, with an increased widening out at the several elbows.

The work was commenced in 1866, and was annually prosecuted to a greater or less extent, under contract and in accordance with the specifications then adopted, until the close of the working-season of 1872. Then, in compliance with the request contained in a communication of December 23, of that year, emanating from a committee of the Chamber of Commerce of Toledo, and addressed to the Secretary of War, but subsequently referred to the Chief of Engineers for his indorsement, the subject of the improvement and preservation of the harbor was submitted to a Board of United States Engineers, with instructions to report a plan for accomplishing the object named, one "affording an entrance-channel of not less than 15 feet depth at the lowest stage of water, and of such width and dimensions as the nature and extent of the commerce of that harbor made desirable."

The report of the Board is to be found published among the documents of the Forty-second Congress, third session, House of Representatives, Ex. Doc. No. 92. Reference to this report is respectfully requested, as it is fully descriptive of Maumee River and Bay, and states the essential requirements to accomplish the desired result of the problem under consideration.

In submitting the report, the Chief of Engineers briefly recapitulates the three plans of improvement as hereinafter enumerated.

> The first being a project for a straight line through North Cape Point, the estimated cost of which is $1,858,500.

This plan, known as that proposed by General Cram, is a prolongation of the Manhattan or inner range of the natural channel, and makes a straight cut from the elbow at the intersection of this range with the middle range, through the North Cape Point, out to the 17-foot curve of the lake, the width to be 250 feet, with a depth of not less than 15 feet. This plan embraces the necessity of closing the mouth of Ten Mile Creek by a dam, and by making a new outlet for it direct into the lake by a cut through North Cape Point.

For a distance of 9,000 feet east of the same point, the cut for the proposed channel is protected on both sides by cribs 20 feet wide and 900 feet apart; on the inside of the point there is no revetment. The length by this cut from Presque Isle Point, mouth of the Maumee River, to the required depth in the lake would be 6.3 miles, or about 1 mile shorter than the present or natural channel.

> The second plan, which is a modification of the preceding, proposes to extend the river *through the bay* and North Cape Point to Lake Erie, confining the river-water in a new channel of about the same dimensions as its natural bed. The estimated cost of this project is $3,074,500.
>
> This plan the Board considers the most complete solution of the problem before it, the result of which can be predicted with the most certainty.

This would be simply the extension of its banks, thereby carrying the river directly out into deep water by the construction of two lines of revetments, consisting of crib-work, for the protection of the two sides of the proposed new channel from its mouth out to the 17-foot curve of the lake. All the details of this plan need not be herein enumerated.

It may be necessary, in order to perfect this plan, at first to assist nature partially by making a cut of about 200 feet in width from the proper depth inside to that outside, but, as the Board remarks, it must not be understood that it is a part of this project to dredge a through-cut 900 feet wide, the width of the river, "because there is a possibility that the river-currents will of themselves dredge out this channel to the same depth as the natural channel above."

The third plan is to improve the existing natural channel through Maumee Bay, the estimated cost of which is $450,000.

By this one the old channel is to be widened for a distance of 7.3 miles to 250 feet, and to the requisite depth of 15 feet. The Board recommended it for adoption for the several reasons stated in the report. The principal one, and a very important one, is that it is the least expensive, and that the estimated cost of either of the other plans would exceed any probable appropriation that Congress is likely to make for this harbor until its importance is more clearly demonstrated.

The committee of the Board of Commerce concurred in these views.

In the "act making appropriations for the repair, preservation, and completion of certain public works" of river and harbor improvement, approved June 23, 1866, and to which the attention of the officer in charge has been invited by the Chief of Engineers, the question is propounded: "As far as practicable, what amount of commerce and navigation would be benefited by the completion of each particular work?" The most reliable and intelligent response to this inquiry can be found among the elaborate and carefully-prepared pages of the "Nineteenth Annual Report of the Trade and Commerce of the City of Toledo for the year ending December 31, 1877; compiled for the Produce Exchange by Dennison B. Smith, Secretary." The information therein contained will convey in a condensed manner the growth and importance of the trade of Toledo during 1877 and several previous years, and the shipment and receipts of flour and grain and miscellaneous articles of produce, both foreign and domestic, through the several channels of supply by rail, lake, and canal.

Some few tables are incorporated in this report from the above-mentioned authority, in order to furnish a brief synopsis of the statistics relating to the shipments made by lake during the year 1877, and thereby show the necessity for the completion of the improvement of the harbor now under consideration. Similar tables for 1876 accompanied the last annual report.

THE GRAIN TRADE.

The following shows the aggregate movement of flour and grain at Toledo during the year ending December 31, 1877:

Supply.

Routes.	Flour.	Wheat.	Corn.	Oats.	Rye.	Barley.
	Barrels.	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels*	*Bushels*
Wabash Railway	272, 530	3, 730, 751	14, 665, 759	1, 431, 387	67, 970	18, 250
Lake Shore and Michigan Southern Railway	121, 377	2, 839, 077	1, 125, 745	689, 989	8, 586	500
Dayton and Michigan Railway	33, 093	632, 486	616, 210	121, 100	4, 550	4, 000
Toledo, Tiffin and Eastern Railway	6, 980	103, 157	880	3, 540		500
Columbus and Toledo Railway	2, 156	93, 159	7, 225	1, 660		
Lake						70, 880
Canal	10, 199	220, 752	134, 970	44, 778	13, 832	
Teams		74, 000	20, 000			
Manufactured here	110, 000					
	556, 335	7, 693, 382	16, 570, 789	2, 292, 445	94, 438	94, 130
In store January 1, 1877		458, 330	1, 018, 769	248, 315	5, 807	72, 189
Total	556, 335	8, 151, 712	17, 589, 558	2, 540, 760	100, 245	166, 310

Disposal.

Lake Shore and Michigan Southern Railway	199,550	2,284,264	3,720,128	88,980	15,355	50
Canada Southern Railway	244,526	886,384	5,552,187	1,031,423	78,647	5,0
Dayton and Michigan Railway	....	294,150	4,800	210,450	....	44,1
Wabash Railway	351	31,038	6,262	....	....	....
Columbus and Toledo Railway	....	25,430	1,762	....	....	....
Toledo, Tiffin and Eastern Railway	9,000	231,284	427,560	700	....	3,0
Lake	2,800	3,316,209	7,606,566	196,356	....	....
Canal	108	42,459	1,720	....	....	....
	456,355	7,111,211	17,300,985	2,307,909	94,002	52,8
Taken by city trade	109,000	524,000	75,748	75,000	....	96,81
In store January 1, 1878	....	516,501	212,825	157,851	6,243	14,6
Total	565,355	8,151,712	17,589,558	2,540,760	100,245	166,3

Recapitulation of receipts of miscellaneous products by lake at the port of Toledo during the season of 1877.

Months.	Lumber.	Laths.	Shingles.	Michigan salt.	New York salt.	Brimstone.	Barley.	Coal.	Sand.
	M.	*M.*	*M.*	*Barrels.*	*Barrels*	*Tons.*	*Bushels.*	*Tons.*	*Barre*
May	18,345	1,202	1,938	15,519	....	100	....	8,923	2,5
June	23,510	3,312	1,247	96,444	1,030	....	....	8,462	1,3
July	21,191	1,427	3,560	26,419	2,800	....	....	3,605	1,3
August	14,890	1,178	1,697	38,532	1,000	....	....	1,967	1,6
September } October }	20,254	1,585	2,333	30,767	13,096	....	10,000	9,160	6
November	15,778	1,902	750	23,070	1,200	....	39,000	6,535	1
December	15,464	1,410	297	25,611	484	....	21,880	5,070	....
Total	129,432	11,961	11,822	256,362	19,610	100	70,880	43,722	7,0

Months.	Stone.	Wood.	Plaster.	Water-lime cement.	Cedar posts.	Gravel.	Pine logs.	Wine.	Iron ore.
	Cords.	*Cords.*	*Barrels.*	*Barrels.*	*Number.*	*Tons.*	*Feet.*	*Bbls.*	*Tons.*
May	256	180	800	1,500	11,700	300	2,000,000	....	....
June	558	105	600	1,510	10,900	....	3,500,000	....	....
July	82	110	500	600	6,500	....	....	....	....
August	96	....	....	1,300	2,575	....	2,000,000	....	....
September } October }	104	567	430	3,560	500	....	....	100	5
November	215	193	2,000	501	....	....	....	....	3,3
December	60	422	....	400	9,600	....	1,000,000	....	....
Total	1,371	1,577	4,330	9,371	41,775	300	8,500,000	100	3,8

Feet of lumber	129,432,0
Logs of lumber (feet)	8,500,0
Total feet of lumber	137,932,0

RECAPITULATION OF SHIPMENTS OF MISCELLANEOUS PRODUCTS BY LAKE AT THE PO OF TOLEDO DURING THE SEASON OF 1877.

Lumber, feet	2,256,6
Staves	2,004,4
Laths	9,0
Shingles	10,0
Timber, cubic feet	1,740,9
Salt, barrels	1

Statement of shipment of flour and grain by lake, and its destination, during the season of navigation in 1877.

Months.	Buffalo.			Ogdensburg.		
	Wheat.	Corn.	Oats.	Flour.	Wheat.	Corn.
	Bush.	*Bush.*	*Bush.*	*Bbls.*	*Bush.*	*Bush.*
April and May	68, 145	330, 048	25, 300	200	60, 248	93, 802
June	16, 000	553, 073		200	6, 262	25, 200
July	16, 000	529, 827			24, 013	45, 400
August	551, 813	615, 463		200	66, 813	43, 400
September	529, 527	134, 490	26, 025	300	74, 562	53, 437
October and November	492, 282	537, 655	26, 180	1, 300	66, 000	104, 160
December	59, 598	278, 480	26, 076	600	40, 517	62, 411
Total	1, 733, 365	2, 979, 036	103, 581	2, 800	338, 415	427, 810

Months.	Oswego.			Sarnia.	Cape Vincent.		Kingston.	
	Wheat.	Corn.	Oats.	Corn.	Wheat.	Corn.	Wheat.	Corn.
	Bush.	*Bush.*	*Bush*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*
April and May	83, 556	248, 255		130, 988		36, 600		144, 399
June	9, 065	58, 831		10, 000				
July	19, 140	46, 975						33, 886
August	59, 350	167, 261	7, 093			19, 300	78, 791	489, 745
September	65, 564	54, 455					234, 232	156, 071
October and November	57, 760	113, 439				16, 378		193, 541
December	46, 141	118, 086			4, 410	15, 350		17, 005
Total	340, 576	807, 302	7, 093	140, 988	4, 410	87, 628	313, 023	1,034, 647

Months.	Cleveland.			Erie.			Belleville.
	Wheat.	Corn.	Oats.	Wheat.	Corn.	Oats.	Corn.
	Bush.	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*
April and May	41, 688		13, 200		193, 281		9, 762
June	48, 971				16, 000		
July	5, 650				238, 098		
August	9, 783			171, 500	66, 998	17, 842	
September and October	17, 340	7, 700	16, 088	36, 990	78, 658		
November	18, 320	9, 900	9, 726	37, 024	90, 849		16, 000
December	15, 904	10, 000		12, 100	99, 655		
Total	157, 656	27, 600	39, 014	257, 614	783, 539	17, 842	25, 762

Months.	Montreal.		Walkerville.	Sacket's Harbor.		Dunkirk.	
	Wheat.	Corn.	Corn.	Wheat.	Corn.	Corn.	Oats.
	Bush.	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*
April and May		285, 592	78, 000	1, 000	7, 000		
June		199, 275		2, 200	6, 800	7, 000	
July	38, 224	299, 562	10, 000	1, 850	7, 150	9, 600	
August	69, 836	159, 908				16, 799	
September and October	41, 953					9, 157	
November		34, 170		3, 980	5, 260	15, 800	11, 326
December			32, 000	9, 000	36, 853		
Total	150, 013	978, 507	120, 000	18, 030	63, 063	58, 356	11, 326

Statement of shipment of flour and grain by lake, &c.—Continued.

Months.	Quebec.	Thorold.	Alpena.		Port Colborne.	Chatham.
	Corn.	Corn.	Wheat.	Oats.	Corn.	Corn.
	Bush.	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*
April and May						
June						
July	22,250	6,721			20,325	2,[illegible]
August				14,000		3,[illegible]
September			3,100			
October and November						
December						
Total	22,250	6,721	3,100	14,000	20,325	5,[illegible]

Months.	Napanee.	Mackinaw.	Black River.	Harrisville.	
	Corn.	Corn.	Corn.	Corn.	Oats.
	Bush.	*Bush.*	*Bush.*	*Bush.*	*Bush.*
April and May					
June					
July	10,200	2,000	4,500	1,000	[illegible]
August					
September					
October and November					
December					
Total	10,200	2,000	4,500	1,000	[illegible]

RECAPITULATION.

	Wheat.	Corn.	Oats.
	Bush.	*Bush.*	*Bush.*
Shipments to American ports	2,853,166	5,241,834	196,[illegible]
Shipments to foreign ports	463,036	2.364,732	
Total	3,316,202	7,606,566	196,[illegible]

Detailed statement of number and tonnage of vessels arrived in the district of Miami for the year 1877.

Months.	Vessels in the coasting trade.	Foreign vessels from foreign ports.	American vessels from foreign ports.	Tonnage.
April	37	21	4	18,[illegible]
May	175	37	10	51,[illegible]
June	254	31	5	[illegible]
July	196	41	4	71,[illegible]
August	239	59	5	90,[illegible]
September	213	38	3	68,[illegible]
October	222	21	3	61,[illegible]
November	181	2	1	46,[illegible]
December	24			8,[illegible]
Total	1,543	250	35	

Grand total, 1,828. Tonnage, 483,855.

Detailed statement of number and tonnage of vessels cleared in the district of Miami for the year 1877.

Months.	Vessels in the coasting trade.	Foreign vessels to foreign ports.	American vessels to foreign ports.	Tonnage.
April	67	15	......	20,393
May	175	42	11	54,189
June	246	82	4	67,848
July	195	46	3	71,607
August	246	59	3	90,087
September	216	81	4	69,586
October	230	23	2	62,358
November	167	2	2	42,319
December	10	....	......	2,869
Total	1,552	250	29	....

Grand total, 2,881. Tonnage, 481,256.

The previous statements furnish the amount of lake commerce during the navigable season of 1877. By a comparison with similar ones in preceding annual reports of the Produce Exchange, there appears to be a very considerable increase of shipment by lake and a decrease by rail. In the last two years the following exhibit is made:

	Bushels.
Shipment by lake, 1877	7,606,566
Shipment by lake, 1876	4,467,375
Increase	3,139,191
Movement by rail, 1877	9,692,699
Movement by rail, 1876	10,780,332
Decrease	1,087,633

"These figures," as stated in the report from which the foregoing tables are extracted, "demonstrate a change from rail to lake of a large quantity of grain, and which will doubtless increase in the future."

The following are the several sources of supply and shipment at the port of Toledo: The Lake Shore and Michigan Southern Railroad; the Wabash Railroad; the Canada Southern Railroad; the Dayton and Michigan Railroad; the Toledo, Tiffin and Mansfield (Pennsylvania Central Division) Railroad; the Columbus and Toledo Railroad; the Toledo and Chicago Air Line; the Toledo and Monroe Narrow Gauge; the Atlantic and Lake Erie Railroad; the Miami and Erie Canal; the lakes; and the home manufactures. The Ann Arbor and Toledo road has just been completed.

The plan of improvement for the harbor of Toledo as finally adopted consists of dredging out the natural or existing channel to a width of 250 feet at the top, and 200 at the bottom, with a depth of 15 feet at an average stage of low-water; also that the sweeps at the angles or elbows, of which there are 4, shall be so rounded and widened as to enable vessels to move from one reach to another, and to pass each other without difficulty or danger of collision.

The work during the fiscal year has been executed under contract. Two separate contracts were entered into. The first was made April 18, 1877, with William Richardson, of Buffalo, N. Y., the amount to be expended not to exceed anallotment of $22,500, authorized to be used from the appropriation of $60,000, approved August 14, 1876. Under this agreement two dredges were put to work.

On the 18th of June a second contract, the amount to be limited to the unallotted balance, $37,500, of the original appropriation, was made with Orville J. Jennings, of Dunkirk, N. Y., to place three additional dredges on the work, with the necessary tugs, dumping-scows, and other appliances.

The first contract, the funds having been exhausted, was closed on the 17th of November, 1877; during its continuance, from April 29 to that date, both inclusive, the quantity of material, sand and clay, dredged and removed amounted to 142,730 cubic yards.

The second contract, the amount allotted for the purpose having been expended, expired on May 29, 1878, and during the execution of the work from the date of its commencement, June 25, 1877, and that of its completion, both inclusive, the quantity of material dredged and deposited upon suitable dumping-grounds, reached 203,128 cubic yards.

The aggregate number of yards displaced under both contracts, from the commencement of the working season of 1877 until the close of the fiscal year 1878, was 345,858, at a cost, including dredging and all incidental expenses of every nature, of $59,623.65.

During the fiscal year, and in the three months preceding it, the operations were confined to the several localities herein indicated along the main or west channel. It may be stated by way of explanation that the term *reaches* is applied to those portions of the channel which extend between the curves or elbows, and that of *ranges* to such reaches as have been marked by main lights and beacons, such as the Inner or Manhattan, the Middle, and the Outer or Phenstock. The reaches, ranges, and elbows which were dredged may be enumerated and described as follows:

No. 1.—This reach, designated the "Outer Reach," or the "Outer Bar," terminates opposite the Turtle Island light-station, its course on entering the harbor being southwest ¼ west. On this reach 5,000 feet, with a width of 200 feet at bottom and a depth of 15 feet, has been dredged out over the bar to the 15-foot curve of the lake at a mean stage of low-water. All the dredges were engaged in operating at this locality during the calm and pleasant weather of August and September, the most favorable months for that purpose. The importance of having a deep and navigable channel at the entrance to the harbor was among the first objects to be secured. There were several additional reasons for working there; among them that, with the shoal places at the outlet of the river into the lake deepened, a great deal of the mud and sand which are now actually deposited at the inner terminus of the "Outer Reach," and at other points above, will be carried out into deep water of the lake by the increased current of the river; also, that should the plan for the improvement of the harbor, known as the "Straight Cut," recommended first by General Cram and subsequently by the Board of Engineers, several years ago, ever be adopted, the work now done on the Outer Reach will be on a direct line with the contemplated straight channel and form part of the proposed improvement, and thus is more in the nature of a permanent and lasting work than the dredging at inner points on the present tortuous channel.

No. 2.—This reach, designated the "South," runs nearly due south, commencing at a point nearly opposite Turtle Island light-station. The dredging extended along it for a distance of 3,400 feet, with a width of 200 feet at bottom and 15 feet in depth.

No. 3.—This reach, the "Southwest," connects the Outer Range and the South Reach. Near its outer terminus, between Red Span Buoys 10 and 12 and Black Cans 5 and 6, there has been dredged 1,600 feet, to a width of 200 feet and depth of 15 feet.

No. 4.—This reach, known as the "Outer or Phenstock Range," has also been dredged. The first cut was 4,400 feet in length, with a width of 125 feet and depth of 15; a partial cut was also made of 2,200 feet in length, with a width of 25 feet and a depth of 15 feet. While engaged on this range during the late working season, it was found necessary to suspend operations, as the appropriation had become exhausted.

No. 5.—This reach, called the "Middle Range," has been dredged its entire length, 1,850 feet. The width of the cut is 125 feet and depth 15 feet.

No. 6.—This reach is designated as the "Inner or Manhattan Range." A cut of 3,200 feet has been dredged, with a width at bottom of 200 feet and a depth of 15 feet.

No. 7.—The elbow at the intersection of the Outer and South Reaches has been dredged so as to make the entire width 410 feet along the radius of the curve.

No. 8.—The elbow at the intersection of the Manhattan and Middle Ranges has also been widened out by dredging so as to increase the width along the radius of the curve to 410 feet.

The channel at the close of the fiscal year was found to be in a good navigable condition, some slight deposits only having been made at the elbows at the end of the working season of 1877, the consequence of the spring freshets and the prevailing strong winds. As one of the results of the beneficial effects of the work last accomplished, it may be mentioned that a number of vessels have lately commenced to sail through the channel, the winds being favorable, and have been able to dispense with the aid of tugs. On several occasions the barge G. W. Adams, in tow of her consort, the propeller Graves, has passed out of the harbor loaded with 70,000 bushels of corn, 1,750 tons, and drawing 13$\frac{2}{12}$ feet of water, bound for Buffalo, N. Y. The Graves carried at the same time 30,000 bushels, drawing a little less than 13 feet. They make about 7 miles per hour, and both carry sails. Upon the completion of the enlargement of the Welland Canal to the contemplated capacity, cargoes of grain can be shipped direct to Europe without breaking bulk.

No exact estimate can be made as to the quantity of material which will need removal during the fiscal year ending June 30, 1880, in order to complete the harbor improvement according to the plan adopted by enlarging the channel to the full dimensions required, as the constant filling in of the dredged cut is being effected to a greater or less extent through the winter and spring months, also during the occurrence of severe gales on the lake, which force the water in or out of the bay and river, at times increasing or decreasing the depth by several feet. The filling in by this constant deposit of sediment can only be prevented by protecting the two sides or banks of the channel with facings of some material sufficiently durable, and laid in accordance with any one of the plans usually adopted for the purpose, such as revetments constructed of sheet-piling through the bay, and piers of crib-work or jetties extended out into the lake.

When this protection is afforded, the work of improvement can be considered permanent and subject only to such repairs as may be needed from time to time. It is estimated that an appropriation of $30,000 will still be required to execute the plan as adopted; the entire amount can be profitably expended during the fiscal year ending June 30, 1880. Small annual expenditures will have to be made after the complete and final cut of the required dimensions has been dredged throughout the entire length of the channel from the river to the lake, in order to remove such material as may be subsequently washed back. The expense of dredging was very considerably reduced during the last fiscal year, and thereby the original estimated cost of this improvement has been somewhat diminished.

The following is a statement of the amounts and dates of all former appropriations which have been already expended on this work of improvement, and also that for the year ending June 30, 1879:

1866	$20,000	1873	$100,000
1867	20,000	1874	75,000
1869	29,700	1875	75,000
1870	50,000	1876	60,000
1871	50,000	1878	50,000
1872	15,000		
		Total	544,700

The abstract of bids received and opened, and the names of the successful bidders, with the dates of the expiration of their contracts, were furnished in the last annual report.

There is a light-house on Turtle Island, at the entrance to Maumee Bay, and three sets of range-lights for the same channel; the light which marks the harbor is a fixed white, of the fourth order. The nearest defensive work is Fort Wayne, near Detroit, distant 45 miles.

Toledo Harbor, Ohio, is in the collection-district of Miami.

Amount of revenue collected during the fiscal year June 30, 1878, $15,702.24.

Entrances and clearances of foreign vessels during the fiscal year ending June 30, 1878: Number, 465; tonnage, 148,440.

Entrances and clearances of American vessels from and to foreign ports: Number, 68; tonnage, 8,610.

Entrances and clearances of coasting vessels: Number, 3,259; tonnage of same, 891,454.

Total vessels, 3,792; tonnage, 1,048,504.

Money statement.

July 1, 1877, amount available	$50,769 35	
Amount appropriated by act approved June 18, 1878	50,000 00	
		$100,769 35
July 1, 1878, amount expended during fiscal year		50,393 00
July 1, 1878, amount available		50,376 35
Amount (estimated) required for completion of existing project		30,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1880		30,000 00

F F 3.

IMPROVEMENT OF PORT CLINTON HARBOR, OHIO.

In order to give a brief history and the condition of this work previous to and during the year ending June 30, 1878, and the progress made up to that date, it will only be necessary at first to submit the following extract from the last annual report. It is ascertained by data furnished in the previous reports made by the several officers in charge during successive years that—

A survey and estimate for the improvement of this harbor were made in 1867, the result having been presented in the report of the Chief of Engineers for 1868. The estimate (approximate) was $89,000. A second survey (with a new project and estimate) was made in 1870 [see report of Chief of Engineers for 1871]; the estimated cost of this project was $120,000. The plan first adopted consisted in deepening by dredging to the dep of 8 feet the long and narrow channel leading from the mouth of Portage River into deep water of the lake; also, by running a timber revetment 1,000 feet in length along the peninsula on the north side of the river at its entrance, for the purpose of protecting it against abrasion by the waves from the lake side, and to act as an impediment to the constant encroachment or drifting of the sand into the channel. The first appropriation for the work was made in 1872, and the work of dredging was then commenced; the cut made, however, was soon filled up by the washing back into the channel of the material taken out. Subsequently, the revetment or catch-sand fence, on the spit forming the left side of the entrance to the river, was constructed and has answered the purpose in checking the movement of sand very satisfactorily.

The second plan, that now adopted for the improvement, in connection with the revetment to which reference has just been made, consists in forming an artificial harbor by confining the flow of the river and directing the course of its current toward the nearest point of the required depth of water in the lake—about along the line where formerly the oldest known channel existed. For this purpose it is intended to build a canal on the prolongation of the river, faced on each side by a revetment or close sheeting of thick plank strongly supported by rows of closely-driven piles, and the whole firmly framed together by heavy timbers; also protected at the bottom by fascines or mill-clippings, loaded down by ripraps of loose blocks of stone, to resist the action of the current and thus prevent undermining.

The work on this plan was commenced in 1875, and continued in that year until the appropriation became exhausted; the west line of revetment, terminating in a bulkhead, was extended at that time from the lower end of the first sand-catch fence northeastwardly into the lake for a distance of 840 feet. The anticipated effect of opening a new channel along it from the scouring effort of the river-current was only partially successful, the tough clay of the bottom resisting with great tenacity a further tendency toward the accomplishment of that purpose. In constructing it nature must be assisted by dredging out a cut through the canal as soon as the sides are completed.

No work was accomplished during the year 1876. The expenditure of the appropriation of $5,000 for that year was not authorized until the early part of May, 1877. As soon as the project for the continuance of the work could be submitted to and approved by the Chief of Engineers, an inspection of the portion executed having been made, and careful soundings taken previously to ascertain the effect produced upon the channel by the construction of the first revetment, the necessary arrangements were made for commencing operations as soon as practicable. The material was purchased in open market, and the work performed by day labor. The construction of the second revetment, on the east side of the entrance to the river, was only commenced on the 25th of June, 1877, after the necessary piles and timber had been furnished and rafted to the locality.

The new revetment, similar in construction to the one already in position, has been built out as far as the very limited appropriation would admit; it terminates in a bulkhead to the south of the first one. In all, 550 feet of revetment have been built. An additional length of 355 feet has still to be constructed. For the present, a clear way of 150 feet has been left open to enable vessels to use the old channel, the latter to be built across and closed up whenever it becomes advisable. Under the new appropriation for the present fiscal year, operations can be readily resumed. The width of the artificial harbor along the first section is to be nearly the same as that of the river, over 300 feet, but gradually narrowing so as not to obstruct too much the flow on the breaking up of the ice at the opening of the spring. From the terminal points, or bulkheads of the two revetments, to a depth of 10 feet of water in the lake sufficient for present purposes, the mean distance is about 1,200 feet. This section of the work, owing to the increased depth of water and to its greater exposure to the action of storms, will have to be constructed with jetties, or the usual crib-work filled with stones, and covered by a flooring of thick plank. Between the jetties of this part the passageway will be narrowed to 200 feet, so as to give greater velocity to the river, and by this means remove to a great extent any deposits which may have a tendency to form along them.

Although from the examinations recently made it is evident that the swift current of the stream, accelerated by spring freshets, has commenced already to open a channel between the revetments of the partially constructed canal, and on the line of least distance to a suitable depth, still a narrow cut will in all probability have to be dredged throughout its entire length to aid the action of the water.

The following is a bill of material expended during the working season of 1877, from June 25 to August 6, both inclusive; at the latter date the appropriation became exhausted:

5,448	feet, board measure, 4 inches by 12 inches oak-waling timber.
2,427	feet, board measure, 3 inches by 8 inches oak-waling timber.
35,370	feet, board measure, 4 inches by 12 inches sheet-piling.
944	feet, board measure, oak planking.
4,675	linear feet, 12-inch round oak piles.
2,470	pounds 1¼-inch screw-bolts.
1,575¼	pounds 7-inch spikes.
236	cords pier-stone.
37	cords mill-clippings.

It is estimated that an appropriation of $65,000 will be necessary for the fiscal year ending June 30, 1880, to insure the entire completion of this work of improvement. It can be safely anticipated that when once accomplished the Portage River, with its waters slightly contracted and its course straightened, will scour by its velocity and keep open the channel, so that little, if any, work of dredging will be afterward required.

As the jetties will be subjected to severe storms and heavy pressure from the ice of winters, there will no doubt be occasional work needed to repair any damages or destruction that may occur to them; they cannot, therefore, be considered permanent structures, and will always require more or less attention. It can at present be but mere conjecture what amount of commerce and navigation would be benefited by the completion of this particular work. The amount of revenue collected for the last few years has certainly not been large.

The following statement shows the amounts appropriated and allotted for this work of harbor improvement, including the fiscal year ending June 30, 1879:

1872	$8,000 00
1873, allotted from appropriation for contingencies of rivers and harbors	2,000 00
1875	5,000 00
1876	5,000 00
1878	10,000 00
Total	30,000 00

The nearest defensive work is Fort Wayne, below Detroit, 60 miles distant. There is a light-house tower in Port Clinton, but the light was extinguished several years ago. The nearest light-house now in use is on Green Island, 10 miles north.

Port Clinton Harbor is in the collection-district of Sandusky, Ohio. Amount of revenue collected during the fiscal year ending the 30th of June, 1878, $125.65.

Entrances and clearances during the fiscal year ending the 30th of June, 1878: number of vessels, 462; tonnage of the same, 34,518.

The sources of supply are by the lake, the Portage River, and Lake Shore and Michigan Southern Railway.

Money statement.

July 1, 1877, amount available	$4,929 93	
Amount appropriated by act approved June 18, 1878	10,000 00	
		$14,929 93
July 1, 1878, amount expended during fiscal year	4,913 83	
July 1, 1878, outstanding liabilities	7 67	
		4,921 50
July 1, 1878, amount available		10,008 43
Amount (estimated) required for completion of existing project		65,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1880.		65,000 00

F F 4.

IMPROVEMENT OF SANDUSKY CITY HARBOR.

To describe the nature of this improvement will be but a repetition of its history as given in the last annual report.

The plan adopted consists in dredging out the natural ship-channel through Sandusky Bay to the east of Johnson's Island, known as the West Channel. Examinations were made, and the question discussed, relative to the merits of what is called the East Channel, which runs close around the west side of Cedar Point, between it and the outer extremity of a large sand spit, and then across the latter in a more direct line toward the city front than by the West Channel. To render the east one serviceable a cut of about 700 feet would have to be dredged over the shoal or sand flat; there is now but 5 or 6 feet of water upon it. There is already evidently a tendency on the part of the lake to work a channel through it. For the reason assigned in the report of the engineer officer then in charge, the West Channel has been preferred, although longer and more tortuous. During the months of May and June, 1877, and through the working season of the fiscal year just closed, the dredging of the west or natural channel progressed in conformity with the specifications of the plan adopted; the width is to be 200 feet at the bottom, with a depth of 15 feet at an average stage of low-water in the lake.

The following is a *résumé* of the work executed during the year. Through the outer bar a cut of about 1,200 feet was made out to the 15-foot curve of the lake, its width being 75 feet with a depth of over 15 feet; to the east of this cut there is a depth of over 14 feet for a width of more than 75 feet, thus making a through channel 150 feet wide and over 14 feet deep. After this cut had been completed, a large steamer, the China, heavily loaded, passed through it with all ease during a northeast storm; the captain reported that while the sea was breaking heavily on each side of it, the water in the cut was comparatively smooth. Along the east and west range, for a distance of 3,650 feet east from the center or main crib, the channel has been completed to the required depth and width. The north and south range, on a line with the main and north cribs, has been entirely completed to its intersection with the range between the west crib and the illuminated clock on the tower of the city hall of Sandusky City.

This last range is on a direct course toward the line of wharves at the foot of Columbia avenue; along it two cuts were completed by the end of the fiscal year, the one 1,200 feet in length, with a width of 100 feet; and the other 1,650 feet with a width of 75 feet. The entire length of the range, which may best be designated for future reference the "illuminated clock range," is 7,150 feet. It extends to a point midway between the two extremities of the city water-front—a compromise direction with which all interests will be satisfied, and convenient in this respect, that the illuminated city-hall clock will serve as a range-light.

Three cuts were dredged on the sweep of the channel, or elbow, at the main crib; length of each cut about 1,000 feet; the width at the axis of the curve is 450 feet. During the present fiscal year it is contemplated to complete the cut through the outer bar, and along the "illuminated clock" or city range.

The appropriation approved August 14, 1876, amounting to $25,000, was not made available until the following year. It was divided into two allotments of $12,500, a separate contract being entered into for each sum. The first was made with Minot Ingalls Wilcox, of Toledo, Ohio, at 11¾ cents per cubic yard, by which one dredge was placed at work on the 3d of May; the second with Orville J. Jennings, of Dunkirk, N. Y., at 11 cents per yard, under which agreement a second dredge commenced operations on the 15th of June. The abstract of bids in each case can be found in the last annual report. Under the first contract, which expired June 19, 1878, the quantity of material dredged and removed during the fiscal year amounted to 57,904 cubic yards; under the second contract, which by its terms should have terminated June 30, 1878, the quantity dredged was 65,050 cubic yards. The sum total taken out from the commencement of the work, under both contracts, until the close of the year amounted to 145,421 cubic yards, at a cost of $22,094.90.

What amount of commerce and navigation would be benefited by the completion of this improvement cannot now be practically determined. The sources of receipt and supply are by the lake and by the three following railways: the Lake Shore and Michigan Southern; the Cleveland, Sandusky and Cincinnati; the Sandusky, Mansfield and Newark (the Lake Erie division of the Baltimore and Ohio). The entire length of the West Channel from the city front to the 15-foot curve in the lake is 4.3 miles. No estimate for a permanent improvement of the harbor can be given, as the channel, not being protected on its sides by revetments, will gradually fill up unless kept open by constant dredging, especially at the elbows and on the outer bar. It will depend upon the price of labor whether the amount appropriated for the fiscal year ending June 30, 1879, will be sufficient to complete the cut throughout its entire length, but there is every reason to believe at this time that such will be the case, although it cannot possibly be known until the next contract is awarded and the price per cubic yard be ascertained. The last contracts were taken at unusually low figures. It may be necessary to submit an estimate at some future time for a continuance of the work during the fiscal year ending June 30, 1880. A small amount, $1,000, is now estimated for to be expended in making such necessary surveys and inspections, and to meet any incidental expenses that may accrue, in order that the officer in charge may be kept properly informed as to the condition and needs of this work of improvement.

There is a light-house on Cedar Point, on the east side of the entrance; the light is a fixed white of the fifth order. Fort Wayne, below Detroit, is the nearest defensive work, 82 miles distant.

Sandusky City Harbor is in the collection-district of Sandusky, Ohio.

Amount of revenue collected during the fiscal year ending June 30, 1878, $4,242.95.

Entrances and clearances during the fiscal year ending June 30, 1878: Number of vessels, 3,172; tonnage of same, 560,603 tons.

The amounts appropriated in each year up to and including June 30, 1879, are as follows:

1844	$15,000 00	1874	$25,000 00
1852	15,000 00	1875	25,000 00
1864	10,000 00	1876	25,000 00
1866	38,580 00	1878	20,000 00
1870	10,000 00		
1872	13,000 00	Sum total	221,580 00
1873	25,000 00		

Money statement.

July 1, 1877, amount available	$21,771 91	
Amount appropriated by act approved June 18, 1878	20,000 00	
		$41,771 91
July 1, 1878, amount expended during fiscal year	16,616 76	
July 1, 1878, outstanding liabilities	2,250 05	
		18,866 81
July 1, 1878, amount available		22,905 10
Amount (estimated) required for completion of existing project		1,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1880		1,000 00

F F 5.

IMPROVEMENT OF HURON HARBOR, OHIO.

The improvement of this locality consists in the building of two parallel piers of crib-work, filled with loose stone and covered with a heavy plank flooring, which form the sides of a canal or artificial harbor. This extends from the mouth of the river Huron in a northeast direction for 1,040 feet, until it reaches a depth of 12 feet of water in the lake, and is 120 feet in width; the channel is 12 feet in depth. The work was commenced in 1826, and completed in 1866. Since then, some minor repairs have received attention. During the past fiscal year no work was executed. At the last inspection it was found that several planks of the flooring had been removed, and some stone taken from the crib-work for ballast. The covering on the shore wing of the west pier is almost entirely gone, and a large quantity of the loose stone removed from it. With these exceptions, the harbor is in good condition. As soon as the appropriation for the present year becomes available, any damage to the piers will be repaired.

The receipts and shipments are made by lake, and by the Lake Shore and Michigan Southern Railway. No estimate is submitted for the fiscal year ending June 30, 1880, as there will probably remain on hand a sufficient balance of the present appropriation to meet any necessary expense.

There is a light-house on the head of the west pier, and an elevated walk placed upon the latter for the use of the keeper; the light is a fixed white of the fourth order. Fort Wayne, below Detroit, 70 miles distant, is the nearest defensive work.

Huron Harbor, Ohio, is in the Sandusky collection-district. Judging from the reports of the past year, the amount of commerce and navigation benefited by the completion of this work has not been large.

Amount of revenue collected for fiscal year ending June 30, 1878, $64.85.

Entrances and clearances during the year ending June 30, 1878: Number of vessels, 252; tonnage, 23,670.

The following statement shows the amount appropriated each year up to and including 1879 for this harbor-improvement:

1826	$5,000 00	1838	$5,000 00
1828	4,413 35	1844	5,000 00
1829	5,935 00	1852	10,000 00
1830	1,880 36	1866	39,000 00
1831	3,480 00	1874	1,500 00
1832	1,500 00	1875	1,000 00
1834	6,700 00	1878	1,000 00
1836	4,300 00		
1837	2,565 00	Total	98,273 71

Money statement.

July 1, 1877, amount available	$189 17	
Amount appropriated by act approved June 18, 1878	1,000 00	
		$1,189 17
July 1, 1878, amount available		1,189 17

F F 6.

IMPROVEMENT OF VERMILLION HARBOR, OHIO.

The plan adopted for this improvement consists in the construction of two parallel piers of crib-work, which extend from the mouth of Vermillion River in a northerly direction out into the lake and form the sides of the canal or artificial harbor. The latter as now built terminates in 12 feet of water; its length is very nearly 1,250 feet, with a width of 100 feet. The piers have been lengthened at different times to meet the demands of the trade. To complete the improvement according to the plan, the channel-way between and along the entire length of the piers, also beyond the pier-heads into the lake as far as the 14-feet curve, has still to be enlarged at some places to the required depth of 14 feet and the proper width of 100 feet, by blasting and displacement of solid rock upon the bottom, and by the dredging and removal of the sand and gravel which have accumulated by deposits from the lake and river. During the fiscal year just closed, no work was attempted further than to improve the condition of the west pier and to attend to needed repairs by replacing old and rotten plank by new ones. The material for the work was purchased in open market, and it was executed by day-labor. The northeast corner of the east pier has commenced to settle. As soon, however, as the dredging of the channel commences and suitable boats for the purpose be obtained, its foundation will be secured from further damage by means of some suitable protection, such as a riprap of brush and loose stone. Owing to the small amount of the balance of the appropriation by act approved August 14, 1876, which remained available at the commencement of the fiscal year, it was not deemed advisable to resume the enlargement of the channel until additional means should be provided. The reasons assigned by those engaged in the business for being unwilling to undertake the work were, that the amount that could then be applied to the purpose was too small to pay for the extra expense of fitting out a dredge with the necessary appliances for blasting under water, and that the cost and risk in sending it to and bringing it back from the locality were too great for the small amount of work to be done. These expenses would demand a price that would seem excessive. The only offer made for dredging both rock and gravel was deemed too high, and very little could have been accomplished at the price. During the fiscal year ending June 30, 1879, there will be available from the balance remaining over from the previous one, together with the appropriation approved June 18, 1878, about $7,000 to be applied to the prosecution of this work. From recent and very careful soundings, it is estimated that by adopting a modification of the original plan, and thereby procure a through channel of 60 feet in width, with a depth of 13 feet out into the lake at an average stage of low-water, the solid and loose rock only to be displaced to a depth of 14 feet, the above amount will be sufficient to accomplish the work. The estimate of rock-excavation by this change would be the same as for a 14-foot channel, but in the latter case there would be a very large increase in the amount of sand and gravel to be removed. In order to procure a complete cut throughout, sufficient for the immediate needs of commerce, it is proposed to adopt for the present the modified plan and await until the necessities of the trade demand the completion of the work according to the original one. For the last few years the revenue collected has been small, and the entrances and clearances of vessels have not been large, nor has there been any apparent increase since the piers have been extended. What amount of commerce and navigation will be benefited in the future will have to be left to conjecture. Stone and lumber are the principal materials shipped to and from this port. The following statements in relation to this harbor have been furnished by prominent dealers in the articles enumerated:

RECEIPTS BY LAKE FROM JULY 1, 1877, TO JUNE 30, 1878.

Pine lumber, feet, board measure	1,790,118
Fence-pickets	11,710
Laths	193,000
Shingles	2,246,500
Salt, barrels	127
Coal, tons	195

SHIPMENTS BY LAKE FROM JULY 1, 1877, TO JUNE 30, 1878.

Block-stone (sandstone), tons	4,638
Grindstones, tons	1,200
Lumber (oak, ash, and sycamore), feet, board measure	300,000
Oak staves	180,000

The stone are all supplied from North Amherst and Brownhelm. The shipment from these two places by rail in 1877 amounted to 35,585 tons of stone, and it is claimed by shippers that one-third of this tonnage will seek water transportation if 13 feet of water can be had in the channel. The sources of supply at this locality are by lake, by the Lake Shore and Michigan Southern Railway, and from the adjacent country. If it is at any time deemed necessary to enlarge the dimensions of the canal in accordance with the plan first adopted, an additional appropriation of $4,000 will be required to complete the drilling, blasting, and removal of the rock, and to dredge and remove the sand and gravel from the bed of the channel. The present repairs to the piers will place them in such excellent order that in all probability no other work will be required for some years to come. They may, however, be subject to damage resulting from exposure to heavy storms and the crushing action of ice at the opening of navigation.

The following bill of material was expended: 10,536 feet, board measure, pine lumber; 8,518 feet, board-measure, oak timber; 22.49 cords stone; 70 1¼-inch drift-bolts; 43 1¼-inch and 1⅜-inch bolts; 172 4-inch by ⅛-inch washers; 267 pounds bolts.

There is a light-house built on the head of the west pier, and an elevated walk constructed on the latter for the use of the keepers; the harbor is marked by a fixed white light of the fifth order. Fort Wayne, below Detroit, 80 miles west, is the nearest defensive work.

Vermillion Harbor is in the Sandusky collection-district.

Amount of revenue collected during fiscal year ending June 30, 1878, $39.80.

Entrances and clearances during the fiscal year ending June 30, 1878: Number of vessels, 83; tonnage of same, 8,314.

The following statement shows the amount appropriated each year up to and including June 30, 1879, for the work of this harbor improvement:

1836	$10,000 00	1874	$3,000
1837	20,000 00	1875	10,000
1838	23,626 57	1876	5,000
1866	15,315 74	1878	4,000
1872	5,000 00		
1873	12,000 00	Total	107,942

Money statement.

July 1, 1877, amount available	$4,113 85	
Amount appropriated by act approved June 18, 1878	4,000 00	
		$8,113
July 1, 1878, amount expended during fiscal year		1,074
July 1, 1878, amount available		7,039

F F 7.

IMPROVEMENT OF BLACK RIVER HARBOR, OHIO.

The plan for this improvement consists in the construction of two piers from the mouth of Black River, inclosing a canal of 150 feet in width and extending 1,350 feet in a northwesterly direction into the lake, until a depth of 15 feet of water is obtained; the channel-way has also been dredged to that depth throughout. The piers are formed of cribs heavily framed and filled with loose stone, a heavy superstructure of plank being placed upon them. This work may be considered as completed so far as appears necessary for vessels now employed in the trade of the lakes. Repairs to the piers will be occasionally required, as they are likely to be more or less damaged by the severe gales and the crushing force of ice during the winter months. The channel within and without the piers may need dredging at times.

This work of improvement commenced in 1828, but it appears the present project was not entered upon until 1864. The piers have been lengthened from time to time, and the channel dredged to corresponding depths, so that they now extend into the lake as far as desirable for present purposes. To enable the keeper to reach the light-house during stormy weather, a raised walk, protected on both sides by railings, has been constructed over nearly the entire length of the west pier. The coal trade at this harbor has been increasing quite rapidly during the last few years, according to recently furnished information, and the lumber trade by the lake is very considerable. As to what amount commerce and navigation will be benefited by enlarging the dimensions of the harbor, it is impossible to estimate. A breakwater across its entrance would render it a safe harbor of refuge. The Black River is navigable for vesels drawing not more than 12 feet of water, over a distance of 4 miles bove its mouth. The direct sources of supply are by the lake, and by he Cleveland, Tuscarawas Valley and Wheeling Railway. When the atter road is completed to Wheeling, W. Va., the harbor will become of in- reased importance. There was no work of any description attempted uring the fiscal year, as no funds remained on hand. An inspection of he harbor was made on the 26th of June last, and it was found that the ast piers had been damaged slightly by some vessel in passing through he canal; also that some planks had been forced from off the cribs at he extremities of the piers. Some few cords of broken stone are needed o replace those that have been taken out of the cribs and used for bal- ast by fishing-boats. Those matters will receive attention as soon as he appropriation for the present fiscal year becomes available. As the outhern extremity of the west pier has been taken possession of by rivate parties, and now used as a wharf, it will not be necessary to lace that portion in repair. No estimate is submitted for the fiscal year nding the 30th of June, 1880.

A light-house has been erected at the entrance to the harbor, on a bulkhead at the uter extremity of the west pier; the light is a fixed white of the fourth order. The earest defensive work is Fort Wayne, below Detroit, 80 miles distant.

Black River Harbor is in the collection district of Cuyahoga. The amount of reve- ue collected during the fiscal year ending June 30, 1878, is $694.30. Entrances and learances during the fiscal year ending June 30, 1878, 649 vessels; tonnage of same, 32,789 tons.

The following statement shows the amount appropriated in each year p to and including 1879.

828	$7,500 00	1864	$20,000 00
830	8,559 77	1866	10,000 00
831	9,275 00	1872	20,000 00
832	8,000 00	1873	20,000 00
833	2,400 00	1874	20,000 00
834	5,000 00	1875	10,000 00
835	4,400 00	1876	6,000 00
836	6,660 00	1878	1,000 00
837	6,410 00		
838	5,000 00	Total	175,204 77
852	5,000 00		

Money statement.

uly 1, 1877, amount available	$52 89	
mount appropriated by act approved June 18, 1878	1,000 00	
		$1,052 89
uly 1, 1878, amount expended during fiscal year	43 04	
uly 1, 1878, outstanding liabilities	9 85	
		52 89
uly 1, 1878, amount available		1,000 00

APPENDIX G G.

ANNUAL REPORT OF MAJOR WALTER McFARLAND, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1878.

UNITED STATES ENGINEER OFFICE,
Oswego, N. Y., September 6, 1878.

GENERAL: I have the honor to transmit herewith my annual reports or the fiscal year ending June 30, 1878, for the harbor improvements in ny charge on lakes Erie and Ontario and the river Saint Lawrence.

Very respectfully, your obedient servant,

WALTER McFARLAND,
Major of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

G G 1.

CONSTRUCTION OF BREAKWATER AT CLEVELAND HARBOR, OHIO.

The work of extending the breakwater has been carried on under the ontract system.

Six cribs, each 50 feet long, have been built, sunk on the broken-stone oundation prepared for them in the fall of 1877, and partially filled ith stone. Two more cribs are in process of construction.

LENGTH OF BREAKWATER JUNE 30, 1878.

	Feet.
ile-pier	1, 000
rib-work extension (completed)	150
rib-work sunk, but incomplete	300
rib-work in process of construction	100
otal length of breakwater when the existing contract expires, September 30, 1878	1, 550
otal length of breakwater proposed by Board of Engineers of June, 1875	7, 100
till to be built	5, 550

The work has been done under the following contracts, viz:

1. Entered into May 23, 1877, with Mr. W. H. McCurdy, Cleveland, hio, for furnishing iron material required in the construction of 300 et of breakwater at the following prices:

Nut, screw and washer bolts, 1,927 pounds, at 3 cents per pound.
Drift-bolts, 3,716, at 1$\frac{7}{10}$ cents per pound.
Spikes, 3,210 pounds, at 2.65 cents per pound.

The iron to be furnished under this contract was delivered and received, nd the contract was closed August 14, 1877.

2. Contract entered into May 23, 1877, with Messrs. Farris & Garfield

of Painesville, Ohio, for furnishing and putting in the breakwater the following material, viz:

All hemlock timber and lumber, at $18.25 per 1,000 feet, board-measure.
All pine timber and lumber, at $18.25 per 1,000 feet, board-measure.
All rubble-stone for foundation and filling cribs, at $4.45 per cord.
All block-stone for riprapping, at $1.20 per ton.

Under this contract work was commenced in the summer of 1877, by laying the rubble-stone foundation, which was completed by the end of September, 1877, 865¾ cords of stone having been put in place, when operations were suspended for the winter.

The crib-work was commenced in April, 1878, and was continued to the end of the fiscal year.

The plan of construction prescribed for the breakwater by the Board of Engineers of June 9, 1875, called for a loose rubble-stone foundation 52 feet in width and 5 feet in height, to be formed by deposit upon the layer of clay and mud which forms the bottom of the lake.

As the bills of material originally furnished the contractor were based on the supposition that this foundation would settle much more than it actually did, there remained on hand after the construction of the six cribs ordered, a surplus of hemlock timber amounting to 63,000 feet board-measure, and as there was a sufficient balance of funds on hand after deducting the amount required under the contract, the building of two additional cribs was ordered, making at the close of this fiscal year eight cribs in process of construction. Six of these have been built to a height of 11 feet, eight courses hemlock and three pine, and have been sunk and partially filled with stone, and the two others are ready for sinking. It is expected that the rest of the crib-work and superstructure will be completed by September 30, 1878, on which date the existing contract expires.

In the construction of the six cribs sunk, the following materials have been used:

Hemlock timber and plank, 156,096 feet, board-measure.
Pine timber and plank 44,054 feet, board-measure.
Rubble-stone, 1,427.15 cords.

Iron:	No.	Pounds
Drift-bolts, 32 inches	2,071	18,
Drift-bolts, 20 inches	553	3,1
Screw and washer bolts	95	2,
Total		24,

It is proposed with the balance available July 1, 1878, to extend the breakwater northwardly a distance of 1,000 feet, under the contract system, and to make such repairs to the piers as may be found necessary, by hired labor and purchase of material in open market.

Cleveland Harbor, Ohio, is in the collection-district of Cuyahoga.
It is lighted by a fixed white light of the third order, with a beacon on each of the two piers.
Nearest defensive work, Fort Wayne, Michigan, 110 miles distant to the westward.

The following statement of the commerce of the port is furnished by the records of the custom-house:

Revenue collected during the fiscal year ending June 30, 1878	$105,435
Value of imports	29,039,667
Value of exports	37,857,726

Number of vessels cleared, 2,732; their tonnage, 1,096,496 tons.
Number of vessels entered, 2,680; their tonnage, 1,076,492 tons.

Money statement.

July 1, 1877, amount available	$35,273 28	
Amount appropriated by act approved June 18, 1878	100,000 00	$135,273 28
July 1, 1878, amount expended during fiscal year	6,782 50	
July 1, 1878, outstanding liabilities	6,405 02	13,187 52
July 1, 1878, amount available		122,085 76
Amount (estimated) required for completion of existing project		1,600,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1880		300,000 00

G G 2.

REPAIRS OF EAST PIER AT CLEVELAND, OHIO.

With the balance of the appropriation of August 14, 1876, work was carried on by hired labor and purchase of material in open market, as follows:

1st. In completing the repair of that part of the east pier occupied by the Cleveland and Pittsburgh Railway Company, under agreement dated February 25, 1877.

This consisted in protecting the stone pier for 50 feet where it had fallen away, with a close row of piling, and an additional length of 352 feet, with a row of piles driven 2½ feet from center to center.

The piles were tied back with iron rods and timbers to a second row of anchor-piles set 30 feet shoreward of the old stone wall and parallel with it.

The whole was covered with a decking of plank.

MATERIALS USED.

Oak timber	34,466 feet, board-measure.
Pine timber	22,663 feet, board-measure.
Screw-bolts	14¼ pounds.
Drift-bolts	150 pounds.
Spikes	2,101 pounds.

These repairs were completed July 18, 1877, and this part of the pier passed, under the terms of the agreement with the honorable Secretary of War, conditionally into the control of the Cleveland and Pittsburgh Railway Company, who are now responsible for its maintenance.

Money statement.

July 1, 1877, amount available	$3,504 25
July 1, 1878, amount expended during fiscal year	3,504 25

G G 3.

IMPROVEMENT OF FAIRPORT HARBOR, OHIO.

Nothing has been done on this improvement during the year, there being no funds available.

An appropriation of $5,000 was asked for in last year's annual report for the extension and repair of the east pier, and this amount was appropriated June 18, 1878. It will be applied during the coming year to the repair of the piers, and to dredging, if found necessary.

Fairport Harbor, Ohio, is in the collection-district of Cuyahoga. It is lighted by a fixed white light of the third order, and a beacon on the east pier.
Nearest defensive work, Fort Wayne, Michigan, 130 miles distant to the westward.

The following statement of the commerce of the port is furnished by the records of the custom-house:

Revenue collected during the fiscal year ending June 30, 1878	$53
Value of imports	No record
Value of exports	No record
Number of vessels cleared	6
Their tonnage, tons	10,6
Number of vessels entered	7
Their tonnage, tons	10,9

Money statement.

July 1, 1877, amount available	$5 48	
Amount appropriated by act approved June 18, 1878	5,000 00	
		$5,005
July 1, 1878, amount expended during fiscal year		5
July 1, 1878, amount available		5,000

GG 4.

IMPROVEMENT OF ASHTABULA HARBOR, OHIO.

Work at this harbor was confined to repairing the piers by hired labor and purchase of material in open market, and to the extension of the west pier by contract, all of which was done under the balance of the appropriation of 1876.

The repairs of the piers consisted in rebuilding the east pier-head and in repairing a breach in the southern (or shore) end of the west pier.

MATERIALS USED.

Stone	80¼	cords.
Pine timber	720	feet, board-measure.
Oak timber	6,856	feet, board-measure.
Iron material	1,351¼	pounds.
Spikes	738	pounds.

On July 5, 1877, contracts were entered into with Mr. W. H. McCurdy, of Cleveland, Ohio, for furnishing the iron required for the extension of the west pier, and with Mr. C. H. Strong, of Cleveland, Ohio, for furnishing all the rest of the material required, and in constructing a crib 40 feet long by 24 feet wide, covered with 6 feet of superstructure.

The crib was sunk in 18 feet of water and the work completed before the close of navigation in 1877.

MATERIALS USED.

Pine timber and plank	67,158	feet, board-measure.
Stone	173	cords.
Drift-bolts	7,195	pounds.
Nut, screw and washer bolts	321¼	pounds.
Spikes	640	pounds.

The west pier at this harbor has been carried 370 feet farther into the lake than the east pier, and the effect of this in dispersing the current of the river over a larger space has been to form a bar obliquely across the mouth of the harbor.

As the extension of the east pier would probably counteract this, and reduce the bar, it is proposed to apply the whole amount now available toward such extension, by which an additional length of 200 feet will be gained, leaving 170 feet still to be built.

The estimated cost of this is $18,000, which it is recommended be appropriated for this purpose.

It appears probable that an extension of both piers 150 feet farther into the lake will be necessary to prevent the continued growth of the bar across the mouth of the harbor, which now hurts the entrance. The cost of such an extension would probably be $24,000.

Ashtabula Harbor, Ohio, is in the collection-district of Cuyahoga, and is lighted by a beacon on the west pier, of the fifth order; description of light, fixed white, varied by white flashes.

Fort Porter, New York, is the nearest fort, 120 miles to the eastward.

The following statement of the commerce of the port is furnished by the records of the custom-house:

Revenue collected during the fiscal year ending June 30, 1878	$549 20
Value of imports	No record.
Value of exports	No record.
Number of vessels cleared	368
Their tonnage, tons	210,629
Number of vessels entered	367
Their tonnage, tons	210,541

Money statement.

July 1, 1877, amount available	$6,584 16	
Amount appropriated by act approved June 18, 1878	12,000 00	
		$18,584 16
July 1, 1878, amount expended during fiscal year		4,597 01
July 1, 1878, amount available		13,987 15
Amount (estimated) required for completion of existing project		18,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1880		18,000 00

G G 5.

IMPROVEMENT OF CONNEAUT HARBOR, OHIO.

The project of improvement of this harbor was completed in 1871, with the exception of dredging in the channel, which has not been found necessary, as the present depth of water, 8 feet, is found sufficient for the requirements of the harbor.

Funds will be needed from time to time for repairs on the piers, but none are required at present.

Conneaut Harbor, Ohio, is in the collection-district of Cuyahoga. It is lighted by a fixed white light of the sixth order, situated on the end of the west pier.

The nearest fort is Fort Porter, New York, 105 miles distant to the eastward.

The following statement of the commerce of the port is furnished by the records of the custom-house:

Revenue collected during the fiscal year ending June 30, 1878	$57 00
Value of imports	No record.
Value of exports	No record.
Number of vessels cleared	10
Their tonnage, tons	780
Number of vessels entered	14
Their tonnage, tons	1,096

Money statement.

July 1, 1877, amount available	$53 5
July 1, 1878, amount available	53 5

G G 6.

IMPROVEMENT OF ERIE HARBOR, PENNSYLVANIA.

During the fiscal year the work at this harbor consisted of—

1. Dredging in the channel.
2. Rebuilding part of the north pier.
3. Extending the catch-sand fence on the neck of the peninsula.

1. Dredging under contract dated April 30, 1877, with Mr. O. J. Je-nings, of Dunkirk, N. Y., was carried out at intervals up to October 3 1877, both between the piers and in the inner channel, but from th date to the close of the fiscal year this operation was suspended.

During this time the dredge was in use 850 hours, and the amount o material taken out is stated by Colonel Blunt to be 16,200 cubic yards.

This contract expires September 30, 1878, by which time it is expected that all the work called for by it will be completed.

2. Rebuilding north pier. Three hundred feet of the superstructur of the north pier was rebuilt from the water-line up, under contrac with Mr. W. H. McCurdy, of Cleveland, Ohio, for iron, and Messrs. Farr & Garfield, of Painesville, Ohio, for timber, stone, and construction.

The work was then protected on the channel side by driving a row o piles in contact with it and from 2 to 3 feet apart and bolting them t the pier.

Before building this superstructure, the rotten timbers, stone, &c. beneath it had to be removed for almost the entire length of 300 feet and in places small cribs had to be sunk for the superstructure to rest o

MATERIALS USED.

Hemlock timber	67,536 feet, board-measur
Pine timber	85,516 feet, board-measur
Beech timber	1,152 linear feet.
Piles	1,368 linear feet.
Stones	314 cords.
Drift-bolts	4,730 pounds.
Screw-bolts	492 pounds.
Spikes	2,324 pounds.

CATCH-SAND FENCE.

The catch-sand fence at the neck of the peninsula was extended wes-wardly 550 feet by a row of beech piles 9 feet apart, driven 11 feet int the sand, planked on the lake side and protected by a riprap of ston. In places a foundation of brush was laid for the stone to rest upon. Th work was completed early in January, 1878.

MATERIALS USED.

Hemlock timber	16,137 feet, board-measur
Stone	65 cords.
Brush	15 cords.
Drift-bolts	125 pounds.
Screw-bolts	488 pounds.
Spikes	525 pounds.

By act approved June 18, 1878, the sum of $25,000 was appropriated for this harbor, giving a balance available at the end of the fiscal year of nearly $41,000.

It is proposed with this—

1. To complete the repair of the north pier by rebuilding the superstructure for 400 feet.
2. To excavate the channel to a depth of 16 feet from the bar outside through the piers to the deep water inside the bay.
3. To continue the construction of the catch-sand fence.

Erie Harbor, Pennsylvania, is in the collection-district of Erie, Pa. It is lighted by 7 lights—a fourth-order lake-coast light on the north shore of the peninsula, fixed white, varied by red flashes; a main harbor light of the third order, fixed white; and five range lights of the sixth order to mark the channels.

The nearest fort is Fort Porter, New York, 90 miles distant to the eastward.

The following statement of the commerce of the port is furnished by the records of the custom-house:

Revenue collected during the fiscal year ending June 30, 1878	$17,085 46
Value of imports	$72,041 00
Value of exports	$55,702 00
Number of vessels cleared	928
Their tonnage, tons	642,588
Number of vessels entered	938
Their tonnage, tons	650,091

Money statement.

July 1, 1877, amount available	$28,521 86	
Amount appropriated by act approved June 18, 1878	25,000 00	
		$53,521 86
July 1, 1878, amount expended during fiscal year	$12,270 65	
July 1, 1878, outstanding liabilities	461 57	
		12,732 22
July 1, 1878, amount available		40,789 64
Amount (estimated) required for completion of existing project		94,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1880.		40,000 00

G G 7.

IMPROVEMENT OF DUNKIRK HARBOR, NEW YORK.

Operations have been carried on during the fiscal year under the contract system, and have been confined to the extension of the breakwater.

On July 5, 1877, a contract was entered into with Mr. W. H. McCurdy, of Cleveland, Ohio, to furnish the iron material needed for the extension at the following rates:

Screw and washer bolts, at 2.8 cents per pound.
Drift-bolts, at 1.85 cents per pound.
Spikes, at 2.8 cents per pound.
Bevel-headed and washer bolts, at 5 cents per pound.

The iron was delivered and the contract closed September 12, 1877.

On July 5, 1877, a contract was also entered into with Mr. O. J. Jennings, of Dunkirk, N. Y., for furnishing the timber and stone needed, and for constructing 250 feet of breakwater, the extension to consist of five cribs, each 30 feet wide by 50 feet long and 8 courses high, surmounted by the form of superstructure prescribed by the Board of Engineers in 1870.

The contract prices were as follows:

Hemlock timber put in place, at $15 per 1,000 feet, board-measure.
Pine timber put in place, at $20 per 1,000 feet, board-measure.
Stone, at $4.50 per cord.

Under this contract work commenced in the fall of 1877, and by the end of November, when work closed for the season, two cribs had been built, filled with stone, and sunk in place, and another was ready for sinking.

On resuming work in the spring it was found that both the sunken cribs had been thrown out of line by wave action during the winter, and before they could be got into place again most of the stone had to be taken out of them.

By the end of the fiscal year all five of the cribs had been built and sunk in place, and the superstructure had been built on them, 251 feet in length, with the exception of a few linear feet of the oak slope.

As the work had been well done, an extension of fifteen days' time on this contract (which expired June 30, 1878) was applied for by the contractor and granted, within which time the work will be completed.

In the construction of these 5 cribs and 251 feet of superstructure the following materials have been used:

Hemlock timber	110,608 feet, board-measure
Pine timber	159,653 feet, board-measure
Oak timber	56,304 feet, board-measure
Total	326,565 feet, board-measure
Stone	631½ cords
Screw and washer bolts	4,252 pounds
Drift-bolts	60,106 pounds
Spikes	2,639 pounds
Total	66,997 pounds

This extension of 251 feet gives the breakwater a total length of 1,191 feet. The proposed length of the breakwater as prescribed by the Board of Engineers in 1870 was 2,860 feet; still to be built, 1,669 feet.

The estimated cost of this work was $275,000, subsequently altered to $350,000, of which $88,000 have been appropriated up to date.

There appears to be no present necessity for constructing the whole of this extension, and I therefore concur in the recommendation made in 1875 and 1876 by Colonel Blunt, that it be made only 1,700 feet long instead of 2,860 feet, which would require an addition of only 510 feet to its present length, the estimated cost of which is $31,000.

The other part of the project of 1870, viz, the excavating a channel between the west pier and breakwater 170 feet wide and 13 feet in depth was completed in 1877.

Total appropriations for Dunkirk Harbor from 1827 to June 30, 1878, $427,343.93.

Dunkirk Harbor, New York, is in the collection-district of Dunkirk. It is lighted by a third-order lake-coast light on the west side of the harbor, fixed white varied by white flashes, and a sixth-order beacon-light on the end of the west pier. A day beacon marks the channel at the mouth of the harbor.

Fort Porter, New York, is the nearest fort, 40 miles distant to the eastward.

The following statement of the commerce of the port is furnished by the records of the custom-house:

Revenue collected during the fiscal year ending June 30, 1878	$221
Value of imports	$707
Value of exports	$16
Number of vessels cleared	
Their tonnage, tons	14,
Number of vessels entered	
Their tonnage, tons	14,

Money statement.

July 1, 1877, amount available		$15,704 62
July 1, 1878, amount expended during fiscal year	$8,175 51	
July 1, 1878, outstanding liabilities	5,028 55	
		13,204 06
July 1, 1878, amount available		2,500 56
Amount (estimated) required for completion of existing project		162,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1880.		31,000 00

G G 8.

IMPROVEMENT OF BUFFALO HARBOR, NEW YORK.

The breakwater has been extended under the contract system by 150 feet of crib-work, on which the superstructure has been commenced, and it is expected that it will be completed by the 30th of September, 1878.

The breakwater has now of completed work a length of	2,924 feet.
Of incomplete work	150 feet.
Total length	3,074 feet.
Still to be built	926 feet.

The appropriation made by act of Congress approved June 18, 1878, will be applied to the further extension of the breakwater under the contract system.

This extension of the breakwater has been made with the balance of the appropriation approved August 14, 1876, allotted May 1, 1877, and in accordance with the plan adopted by the Board of Engineers in 1873 and 1874.

After due advertisement contracts were entered into for the extension of the breakwater 150 feet southwardly, as follows:

1. With Mr. W. H. McCurdy, of Cleveland, Ohio, July 25, 1877, for furnishing all the iron material needed at the following prices:

	Pounds.
Screw and washer bolts, at $3.10 per 100 pounds	1,054
Drift-bolts, at $1.70 per 100 pounds	96,674
Wrought-iron spikes, at $2.90 per 100 pounds	2,737
Total amount	100,465

The iron to be furnished under this contract was received September 15, 1877, and the contract was closed.

2. With Mr. Ambrose Clark, of Buffalo, N. Y., for furnishing and putting in place the materials to be used in the extension of the breakwater, as follows:

All pine timber and lumber at $18 per 1,000 feet, board-measure.
All Hemlock timber and lumber at $15 per 1,000 feet, board-measure.
All stone for cribs, superstructure, riprap, and filling of trench, at $4.50 per cord.
All gravel filling for trench at $1 per cubic yard, and for dredging a trench for the foundation of the cribs at 75 cents per cubic yard.

This contract expires September 30, 1878.

Dredging the trench for the foundation of the cribs was commenced immediately on signing the contract, and was finished by the end of September, 1877.

Amount excavated	2,814 cubic yards.

By the end of October the trench had been filled with 2,395 cubic yards of gravel to a height of 9 feet, surmounted by 3 feet of stone filling, amounting to 88.35 cords, thus completing the foundation for the cribs.

During the winter operations were suspended, but were resumed early in February, 1878, by the construction of crib-work.

Before the close of the fiscal year three cribs, each 50 feet long by 38 feet by 30 feet, constituting the proposed 150 feet extension under this contract, had been built, filled with stone, and sunk in place in an average depth of 30 feet of water, and the framing of the superstructure for them had been commenced. In their construction the following materials have been used:

Hemlock timber and plank	353, 609 feet, board-measure.
Pine timber and plank	36, 720 feet, board-measure.
Total timber	400, 329 feet, board-measure.
Stone, cords	1, 105.36
Iron:	Pounds.
Screw and washer bolts, No. 60	1, 054
Drift-bolts, No. 3,960	75, 552
Spikes	442
Total iron	77, 048

The superstructure of these cribs will probably be finished by September 30, 1878.

The appropriation of $80,000, made by act of Congress approved June 18, 1878, will be applied to the further extension of the breakwater southwardly, the length to be added being probably 350 feet.

Buffalo Harbor, New York, is in the collection-district of Buffalo Creek, New York. It is lighted by one third-order fixed white light on the south side of Buffalo Creek at the end of the pier, to which light-station a fog-bell is attached; a fixed red fourth-order beacon on the north end of the breakwater, and a fourth-order fixed white light varied by white flashes on Horse Shoe Reef Shoal, marking the entrance to the Niagara River. There is also a fog-bell attached to this beacon on the breakwater.

Fort Porter is within city limits.

The following statement of the commerce of the port is furnished by the records of the custom-house:

Revenue collected during the fiscal year ending June 30, 1878	$421, 734
Value of imports	$2, 241, 345
Value of exports	$190, 477
Number of vessels cleared	4, 051
Their tonnage, tons	2, 127, 215
Number of vessels entered	3, 972
Their tonnage, tons	2, 110, 832

Money statement.

July 1, 1877, amount available	$36, 522 37	
Amount appropriated by act approved June 18, 1878	80, 000 00	
		$116, 522 37
July 1, 1878, amount expended during fiscal year	12, 829 91	
July 1, 1878, outstanding liabilities	11, 579 45	
		24, 409 36
July 1, 1878, amount available		92, 113 01
Amount (estimated) required for completion of existing project		1, 735, 000 00
Amount that can be profitably expended in fiscal year ending June 30, 1880.		300, 000 00

G G 9.

IMPROVEMENT OF WILSON HARBOR, NEW YORK.

The appropriation of $10,000 of August 14, 1876, was not made available until May 2, 1877, when authority was obtained to carry on the work by hired labor and purchase of material in open market.

Under this authority, four cribs, 16 feet by 30 feet=120 linear feet, one of 5 courses in height, two of 4 courses, and one of 3 courses, were built and sunk on the foundation of the old work at the south or shore end of the west pier, and were covered with 4 courses of superstructure.

The superstructure on the old work to the north of this crib-work was also rebuilt for 80 feet in length—4 courses of 20 feet and 3 courses of 60 feet.

In this work the following materials were used, the cost of labor being $562.25:

Timber, feet, board-measure	57,720
Plank, feet, board-measure	19,469
Total feet, board-measure	77,189
Stone, cords	108.8
Drift-bolts, pounds	7,298
Screw and washer bolts, pounds	1,754
Spikes, pounds	1,400
Total pounds	10,452

DREDGING.

The channel had been closed by a mass of sand, which had washed in through the break in the west pier, forming a bar 40 feet in width and 3 to 6 feet in height above water, stretching from pier to pier.

An agreement was entered into with Mr. H. J. Mowry, of Syracuse, N. Y., to dredge the channel down to 9 feet below zero of the gauge at 18 cents per cubic yard for material measured in place.

Work was commenced by the dredge in the middle of September, 1877, and was continued until the beginning of November, when it stopped for the winter, but resumed operations April 15, 1878, and by the end of June the work was completed. During that time 14,302 cubic yards of sand and gravel were taken out.

The harbor is now open to vessels drawing 8 feet of water at lowest stage, or 10 feet at mean lake-level.

It is proposed with the balance of the appropriation, after paying for the dredging, to rebuild the superstructure of the east pier for a length of 322 feet and to protect the beach at the shore end of the west pier by a row of pilings sheathed with timber 120 feet in length.

Wilson Harbor, New York, is in the collection-district of Niagara, at the mouth of Twelve Mile Creek, 12 miles east of the mouth of Niagara River and 6 miles west of the harbor of Olcott, where is situated the light-house nearest to Wilson Harbor.

The nearest fort is Fort Niagara, 12 miles distant to the westward.

The following statement of the commerce of the port is furnished by the records of the custom-house:

Revenue collected during the fiscal year ending June 30, 1878	$418 30
Value of imports	$1,855 00
Value of exports	$639 45
Number of vessels cleared	[illegible]
Their tonnage, tons	1,3
Number of vessels entered	
Their tonnage, tons	1,3

Money statement.

July 1, 1877, amount available		$10,018 45
July 1, 1878, amount expended during fiscal year	$5,171 16	
July 1, 1878, outstanding liabilities	1,418 56	
		6,589 72
July 1, 1878, amount available		3,428 73
Amount (estimated) required for completion of existing project		80,000 00

G G 10.

IMPROVEMENT OF OLCOTT HARBOR, NEW YORK.

Nothing has been done at this harbor during the year, no funds being available.

To complete the original project of improvement there still remains to be built 100 feet of pier-work on each side of the channel; and to be removed from between the piers 2,600 cubic yards of sandstone and 6,000 cubic yards of sand, clay, and gravel; and 2,500 cubic yards of similar material from the inner basin or harbor.

The estimated cost of this work is $10,000, all of which might profitably be expended within the next fiscal year.

Olcott Harbor, New York, is in the collection-district of Niagara, at the mouth of Eighteen Mile Creek, 18 miles east of the mouth of Niagara River and of Fort Niagara, and is lighted by a sixth-order light erected near the head of the west pier.

The following statement of the commerce of the port is furnished by the records of the custom-house:

Revenue collected during the fiscal year ending June 30, 1878	$66 2
Value of imports	882 0
Value of exports	13,709 0
Number of vessels cleared	64
Their tonnage, tons	3,2
Number of vessels entered	64
Their tonnage, tons	3,24

Money statement.

July 1, 1877, amount available	$63 2
July 1, 1878, amount expended during fiscal year	63 2
Amount (estimated) required for completion of existing project	10,000 0
Amount that can be profitably expended in fiscal year ending June 30, 1880	10,000 0

G G 11.

IMPROVEMENT OF OAK ORCHARD HARBOR, NEW YORK.

Operations under the appropriation of $2,000, approved August 14, 1876, and made available May 2, 1877, were as follows:

The deck-plank on 210 linear feet of the west pier was removed, the superstructure leveled up for that distance, and the decking replaced.

The breach at the inner end of the east pier was partly closed by sinking in it three cribs 10 feet by 30 feet and rebuilding 100 linear feet of the superstructure.

A length of 30 linear feet of the inner end of the east pier, undermined by dredging, was refilled with stone.

In this work the following materials were used, the total cost of the labor being $295.47:

Timber, feet, board-measure	27,874
Plank, feet, board-measure	4,780
Total feet, board-measure	32,654
Drift-bolts, pounds	4,026
Screw and washer bolts, pounds	648
Spikes, pounds	600
Total pounds	5,274
Stone, cords	$41\frac{25}{100}$

It is proposed with the appropriation of $2,000, made by act of Congress approved June 18, 1878, to finish the repairs at the shore end of the east pier and to remove part of the sand and gravel which has been washed into the channel.

Oak Orchard Harbor, New York, lies in the collection-district of Genesee, nearly midway between the mouths of the Genesee and Niagara rivers, 30 miles distant from the former and about 45 miles from the latter, and forms the only good harbor of refuge lying between these points. It is lighted by a fourth-order light situated at the outer end of the west pier.

The following statement of the commerce of the port is furnished by the records of the custom-house:

Revenue collected during the fiscal year ending June 30, 1878	$2,673 18
Value of imports	13,880 00
Value of exports	217 00
Number of vessels cleared	21
Their tonnage, tons	1,221
Number of vessels entered	27
Their tonnage, tons	1,789

Money statement.

July 1, 1877, amount available	$2,001 52	
Amount appropriated by act approved June 18, 1878	2,000 00	
		$4,001 52
July 1, 1878, amount expended during fiscal year		1,574 86
July 1, 1878, amount available		2,426 66
Amount (estimated) required for completion of existing project		2,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1880		2,000 00

G G 12.

IMPROVEMENT OF CHARLOTTE HARBOR, NEW YORK.

Nothing has been done here, as only the sum of $22.54 was available at the beginning of the fiscal year for the improvement of this harbor.

By act of Congress approved June 18, 1878, the sum of $1,000 was appropriated, which will be applied, by hired labor and purchase of material in open market, to the repair of the piers.

The original scheme for the improvement of this harbor has been carried out, but a yearly sum of $1,000 will probably be needed for repairs.

Charlotte Harbor, New York, is in the collection-district of Genesee, and is the port of the city of Rochester, 7 miles distant.

The harbor is formed by the mouth of the Genesee River.

For a history and sketch of it, see Report of the Chief of Engineers for the fiscal year ending June 30, 1876.

The following statement of the commerce of the port is furnished by the records of the custom-house:

Revenue collected during the fiscal year ending June 30, 1878	$26,781 29
Value of imports	173,332 00
Value of exports	393,596 00
Number of vessels cleared	571
Their tonnage, tons	119,303
Number of vessels entered	557
Their tonnage, tons	116,584

Money statement.

July 1, 1877, amount available	$22 54	
Amount appropriated by act approved June 18, 1878	1,000 00	
		$1,022 54
July 1, 1878, amount expended during fiscal year		22 54
July 1, 1878, amount available		1,000 00
Amount that can be profitably expended in repairs in fiscal year ending June 30, 1880		1,000 00

G G 13.

IMPROVEMENT OF PULTNEYVILLE HARBOR, NEW YORK.

Under the appropriation of $3,000 for this harbor, approved August 14, 1876, and made available May 2, 1877, work was carried on as follows:

The east pier was extended shoreward 90 feet by adding three cribs of five courses high and each 30 feet in length; one 20 feet wide and two 15 feet wide.

The superstructure on the shore end of the west pier was rebuilt for 150 linear feet.

The north ends of both piers were also rebuilt, one for 10 feet and the other 15 feet back from the lake ends.

In this work the following materials were used, the total cost of labor being $478.76:

Timber, feet, board-measure	45,200
Plank, feet, board-measure	11,106
Boards, feet, board-measure	88
Total, feet, board-measure	56,394
Drift-bolts, pounds	7,294
Screw and washer-bolts, pounds	1,316
Spikes, pounds	692
Total, pounds	9,302
Stone, cords	85$\frac{55}{128}$

It is proposed with the appropriation of $5,000 approved June 18, 1878, to close the opening between the east pier and the shore by hired labor and purchase of material in open market, and to apply the balance to dredging in the harbor.

Pultneyville Harbor, New York, lies in the collection-district of Genesee, about 40 miles west of Oswego, and a little over 20 miles east of the mouth of the Genesee River.

The nearest light-house is at Great Sodus Bay, about 12 miles east of Pultneyville.

The following statement of the commerce of the port is furnished by the records of the custom-house:

Revenue collected during the fiscal year ending June 30, 1878	$1,372 11
Value of imports	$7,050 00
Value of exports	$463 00
Number of vessels cleared	51
Their tonnage, tons	1,410
Number of vessels entered	51
Their tonnage, tons	1,678

Money statement.

July 1, 1877, amount available	$3,039 44	
Amount appropriated by act approved June 18, 1878	5,000 00	
		$8,039 44
July 1, 1878, amount expended during fiscal year		2,415 93
July 1, 1878, amount available		5,623 51
Amount (estimated) required for completion of existing project		13,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1880		13,000 00

G G 14.

IMPROVEMENT OF GREAT SODUS HARBOR, NEW YORK.

The appropriation of $5,000 made by act of Congress approved August 14, 1876, was made available May 2, 1877, and has been applied to the repair of the west pier and the building of an additional sand-catch fence and 50 linear feet of sheet-piling along the west face of the west pier.

The sand-catch fence, 300 feet in length, was built parallel to the west pier, beginning at the west end of the shore arm; 207 linear feet of the superstructure of the shore arm of the west pier was rebuilt 10 feet in width and three and four courses in height, and 150 feet of the lake arm was also rebuilt to three and four courses in height; and some minor repairs were made to the east pier. Sixty feet of sheet-piling was also built from the end of the old sand-catch fence along the face of the west pier lakeward.

In this work the following materials were used, the cost of the labor being $1,076.70:

Timber, feet, board-measure	56,554
Plank, feet, board-measure	27,212
Boards, feet, board-measure	50
Total, feet, board-measure	83,816
Drift-bolts, pounds	11,102
Spikes, pounds	1,600
Iron, pounds	156
Nails, pounds	170
Total, pounds	13,028
Linear feet of piling	672

It is proposed to apply the appropriation of $5,000 made by act of June 18, 1878, to the repairs needed on both piers, and to dredging in the channel under contract.

Great Sodus Harbor, New York, is in the collection-district of Oswego, and is distant about 32 miles from Fort Ontario, at Oswego. It is lighted by a fourth-order coast white flash-light on the bluff west of the entrance, and by two white beacon-lights at the ends of the west pier.

The following statement of the commerce of the port is furnished by the records of the custom-house:

Revenue collected during the fiscal year ending June 30, 1878	$1,211 28
Value of imports	$6,521 00
Value of exports	$1,631 00
Number of vessels cleared	145
Their tonnage, tons	15,452
Number of vessels entered	[illegible]
Their tonnage, tons	8,367

Money statement.

July 1, 1877, amount available	$6,472 09	
Amount appropriated by act approved June 18, 1878	5,000 00	
		$11,472 09
July 1, 1878, amount expended during fiscal year		3,571 23
July 1, 1878, amount available		7,900 86
Amount (estimated) required for completion of existing project		5,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1880		5,000 00

G G 15.

IMPROVEMENT OF LITTLE SODUS HARBOR, NEW YORK.

With the balance of the appropriation of August 14, 1876, made available May 2, 1877, work was continued as follows, by the system of hired labor and the purchase of material in open market:

Three hundred and fifty feet of the superstructure of the west pier, which had settled from 1 to 2 feet, was leveled up and filled with stone.

The east breakwater was extended 150 feet shoreward by 5 cribs, 3 feet in height, covered with 2 feet of superstructure.

In this work the following materials were used, the total cost of labor being $953.39:

Timber, feet, board-measure	63,867
Plank, feet, board-measure	18,917
Total, feet, board-measure	82,784
Drift-bolts, pounds	5,068
Screw and washer bolts, pounds	1,984
Spikes, pounds	2,300
Iron, pounds	47
Nails, pounds	40
Total pounds	9,439
Stone, cords	185.43

It is proposed, with the appropriation of $10,000 made by act of Congress approved June 18, 1878, to make the repairs needed on both piers, and to do some dredging by contract in the channel.

Little Sodus Harbor, New York, is in the collection-district of Oswego, about 15 miles west of Fort Ontario, at Oswego. The harbor is lighted by a fixed white light of the fourth order, placed near the head of the west pier.

The following statement of the commerce of the port is furnished by the records of the custom-house:

Revenue collected during the fiscal year ending June 30, 1878	$22,222 90
Value of imports	$97,342 00
Value of exports	$34,228 00
Number of vessels cleared	250
Their tonnage, tons	28,848
Number of vessels entered	230
Their tonnage, tons	17,370

Money statement.

July 1, 1877, amount available	$5,856 57	
Amount appropriated by act approved June 18, 1878	10,000 00	
		$15,856 57
July 1, 1878, amount expended during fiscal year		3,911 40
July 1, 1878, amount available		11,945 17
Amount (estimated) required for completion of existing project		7,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1880.		7,000 00

G G 16.

IMPROVEMENT OF OSWEGO HARBOR, NEW YORK.

Operations have been carried on during the fiscal year with the balance of the appropriation of August 14, 1876, under the system of hired labor, and by the purchase of material in open market.

The new breakwater has been extended 423 feet, making its present length as follows:

	Feet.
Shore arm	910
Lake arm	3,206
Total length	4,116
Original estimated length	5,800
Amount still to be built	1,684

Original estimated cost	$1,162,682 00
Appropriated to June 30, 1878	605,000 00
To be appropriated	557,682 00

Besides the extension of the new breakwater, repairs to the amount of $3,500 have been made to the older parts of it, and $3,000 have been expended on repairs to the old breakwater.

EXTENSION OF NEW BREAKWATER.

As soon as the balance of the appropriation of 1876 ($60,000) was made available, arrangements were made for the purchase of material, and the work of framing timber for the crib-work was commenced early in August, 1877.

By the end of September 12 cribs each 35 feet square had been completed and sunk in position, in an average depth of 19 feet of water on a hard bottom. A counterfort 30 feet square was also sunk in rear of the two outer cribs. Owing to the difficulty of procuring the long timber used on such short notice, the pine superstructure which covered the crib-work was not finished until the first week in December.

In this work the following materials were used, the cost of labor being $7,070.65, viz:

Timber, pine, feet, board-measure	299,653
hemlock, feet, board-measure	632,256
oak, feet, board-measure	24,668
Plank, pine, feet, board-measure	46,206
hemlock, feet, board-measure	22,946
oak, feet, board-measure	72
Boards, pine, feet, board-measure	79
Total lumber, feet, board-measure	1,022,631
Iron:	
Drift bolts, pounds	92,686
Headed bolts, pounds	1,753
Screw and washer bolts, pounds	6,251
Spikes, pounds	5,224
Washers, pounds	33
Nails, pounds	145
Flat iron, pounds	4,15
Total iron, pounds	111,13
Stone, cords	2,840.6
Tallow, pounds	5

The repairs to the outer breakwater consisted in leveling up 125 fee of the shore arm and 248 feet of the lake arm which had settled from to 3 feet.

The lake ends of the deck plank were protected for a distance of 41 feet by bolting 6-inch by 12-inch pine stringers upon them. Three hundred and ninety linear feet of flat iron 2 inches by ⅜ inch were spiked upon the deck plank and three courses of superstructure were added t the lake side of one of the cribs.

In this work the following materials were used, the cost of the labor being $1,422.80:

Timber, pine, feet, board-measure	15,8
hemlock, feet, board-measure	1,6
oak, feet, board-measure	13,6
Plank, pine, feet board-measure	31,6
Oak, feet, board-measure	23
Boards, pine, feet, board-measure	21
Total lumber, feet, board-measure	63,2
Wedges, wood, number	7
Stone, cords	123.4
Iron:	
Drift-bolts, pounds	5,1
Screw and washer bolts, pounds	3
Spikes, pounds	2,9
Flat iron, pounds	1,3
Total iron, pounds	9,5

The repairs to the old breakwater were as follows:

Old material was replaced by new along the face of the north wall for 195 feet in length, and from six to ten courses in height; three courses in height 61 feet long were removed and replaced by new material, and minor repairs of the same character were made amounting in length t 145 feet.

The deck-plank and joists were removed to admit of these repairs and replaced.

A crib 6 feet 9 inches by 5 feet 9 inches by 3 feet was sunk in th northwest corner of the beacon-pier to stop the washing out of the stone filling. Three shields 20 feet by 1 foot by 2 feet each were bolted upon the face of the north wall, three snubbing-posts were taken up and replaced by new ones, and the face of the north wall was dressed and sheathed with 3-inch plank for 272 feet.

In this work the following materials were used, the cost for labor being $1,431.86:

Timber, hemlock, feet, board-measure	7,764
pine, feet, board-measure	35,292
oak, feet, board-measure	33
Plank, oak, feet, board-measure	7,961
Total lumber, feet, board-measure	51,050
Iron:	
Drift-bolts, pounds	6,723
Screw and washer bolts, pounds	365
Spikes, pounds	4,077
Washers, pounds	19
Nails, pounds	10
Sledges, pounds	25
Total iron, pounds	11,219
Stone, cords	88.95
Ratline, pounds	8¼
Rope, manilla, pounds	28

With the appropriation made available June 18, 1878, it is proposed to extend the new breakwater 200 feet this fall, if possible, and 400 feet next spring by the use of hired labor and the purchase of materials in open market.

As the bed of the lake within 100 feet of the end of the present work is covered with several feet of sand, it may be necessary to resort to dredging.

This and an increased depth of from 2 to 4 feet of water will probably increase the cost over that of last year, which, including all expenses, was about $101 a running foot of pier.

Oswego Harbor is in the collection-district of Oswego, and is lighted by a fixed white light of the third order, and by a red beacon light at the outer end of the old breakwater.

Fort Ontario is situated a little to the east of the east pier, and commands the harbor.

The following statement of the commerce of the port is furnished by the records of the custom-house:

Revenue collected during the fiscal year ending June 30, 1878	$416,025 10
Value of imports	$4,718,660 00
Value of exports	$960,862 00
Number of vessels cleared	2,238
Their tonnage, tons	397,866
Number of vessels entered	2,376
Their tonnage, tons	428,764

Money statement.

July 1, 1877, amount available	$58,470 01	
Amount appropriated by act approved June 18, 1878	90,000 00	
		$148,470 01
July 1, 1878, amount expended during fiscal year		53,407 11
July 1, 1878, amount available		95,062 90
Amount (estimated) required for completion of existing project		557,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1880.		300,000 00

G G 17.

IMPROVEMENT OF OGDENSBURGH HARBOR, NEW YORK.

Nothing has been done on this improvement during the past year, as there have been no funds available for it.

The original project has been completed with the exception of the construction of the pile piering proposed to prevent the waters of the Oswegatchie from wasting their force by spreading over the shoal which lies in front of the city.

The estimated cost of this part of the improvement was $70,000, but there appears to be no present necessity for its construction, and no further appropriation is, therefore, asked for.

There are two steam ferries at this port running to Prescott, one connecting the Grand Trunk Railway and Lake Champlain Railroad; the other making half-hourly trips with passengers from between the two towns.

Ogdensburgh Harbor, New York, is in the collection-district of Oswegatchie, about 120 miles from Fort Ontario, at Oswego, and is lighted by a fixed white light of the fourth order.

The following statement of the commerce of the port is furnished by the records of the custom-house:

Revenue collected during the fiscal year ending June 30, 1878	$97,081 3
Value of imports	$628,28
Value of exports	$570,360 0
Number of vessels cleared	97
Their tonnage, tons	184,4
Number of vessels entered	1,0
Their tonnage, tons	188,13

Money statement.

July 1, 1877, amount available	$15 08	
December 11, 1877, amount allotted from the appropriation for repairs of harbors on northern lakes	5 56	
		$20 6
July 1, 1878, amount expended during fiscal year		20 6
Amount (estimated) required for completion of existing project		70,000 0

G G 18.

IMPROVEMENT OF WADDINGTON HARBOR, NEW YORK.

No funds were available during the past fiscal year for the improvement of this harbor, and none were asked for, the improvement as originally designed being complete.

The $5,000 appropriated by act of Congress approved June 18, 1878 will be applied, however, to the further improvement of the river channel by dredging.

Waddington Harbor, New York, is in the collection-district of Oswegatchie, on the Saint Lawrence River, about 20 miles below Ogdensburgh, where the nearest American light-house is situated. It is about 100 miles from Fort Montgomery, at Rouse's Point.

The following statement of the commerce of the port is furnished by the records of the custom-house:

Revenue collected during fiscal year ending June 30, 1878	$7,718 77
Value of imports	$52,327 00
Value of exports	$17,206 00
Number of vessels cleared	14
Their tonnage, tons	735
Number of vessels entered	18
Their tonnage, tons	956

Money statement.

Amount appropriated by act approved June 18, 1878	$5,000 00
July 1, 1878, amount available	5,000 00

APPENDIX H H.

ANNUAL REPORT OF MAJOR G. H. MENDELL, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1878.

UNITED STATES ENGINEER OFFICE,
San Francisco, Cal., July 5, 1878.

GENERAL: I have the honor to transmit the annual reports for the year ending June 30, 1878, of the works of river and harbor improvement under my charge.

Very respectfully, your obedient servant,

G. H. MENDELL,
Major of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

H H 1.

IMPROVEMENT OF OAKLAND HARBOR, CALIFORNIA.

HISTORY.

Oakland lies upon the eastern shore of the bay of San Francisco, opposite to and 5 miles distant from the city of San Francisco. The great width and depth of the bay, and some known difficulties of construction, have thus far made the bay an effectual barrier to the extension of railroad lines from the eastern shore to the city of San Francisco. Owing to this circumstance Oakland has become the terminus of the system of railroads of the State.

The frontage of Oakland on San Francisco Bay is over a gently sloping beach which reaches out more than 2 miles into the bay before it affords sufficient depth for commercial purposes. A wooden pier more than 2 miles long stretches from the shore to deep water. At the western end of this pier the exchange of passengers and freight takes place, and over this pier passes the greater part of the railroad traffic of the State, including an enormous ferry travel between San Francisco and Oakland. The inconvenience of an exchange of passengers and freight in the middle of the bay, the insecurity of a wooden pier, although cared for with great vigilance, exposed, as it necessarily is to the hidden and destructive attacks of marine insects, and the possibility of accidents involving frightful loss of life, form the principal arguments for undertaking the construction of an artificial harbor.

The opportunity to make an artificial harbor is offered by the estuary of San Antonio, which extends inland for something over 2 miles on the southern boundary of the city of Oakland, and opens into the main bay opposite to the city of San Francisco.

The area of this estuary at high-water is about 825 acres, and the rise of the tide above its lowest ebb is 9 feet, the mean rise being considerably less.

A study of this estuary showed that the reciprocal action of the flood and ebb tides was able to maintain at the outlet of the harbor a channel 450 feet wide, with a maximum depth of 18 feet, but so soon as the tidal currents lost the strength due to the guiding of the shores and began to traverse the flat beach intervening between the shores and deep water in San Francisco Bay, they were unable, owing to their dispersion, to resist the accumulated sands and to maintain a practicable channel. The obvious remedy was to restore strength to the tidal action by guiding the currents between jetties extending from the Oakland shore to the deep water of San Francisco Bay. Inasmuch as this tidal action has for years maintained a good channel of 18 feet in depth at the mouth of the harbor, we cannot doubt that the same force will maintain throughout the length of the jetties, and for some distance beyond their farther ends, an equal width and an equal depth.

If, however, it be thought desirable to secure and maintain a channel of much greater width or depth than is possessed by the natural channel, it is equally plain that this result cannot be obtained by the tidal volume due to the area of the estuary above in its present condition. In order to secure this result the volume of the tidal prism which ebbs and flows between the jetties must be increased. Increase of volume may be given both by dredging the shoals in the upper part of the estuary and by turning into the estuary a portion of the tidal waters of San Leandro Bay, the head of which is little over a mile distant from the head of San Antonio estuary. This may be done by connecting the two estuaries by a large canal which will be something more than a mile in length.

The land drainage plays no part among the forces which are relied upon to produce results. The only streams which enter these estuaries are small rivulets which flow for a few months in the year, and in that time it may be doubted whether any addition they make to the force of the ebb is not more than counterbalanced by the freight of soil they deposit in the tidal basin. The forces to be used are, therefore, simply tidal. This, it may be remarked, is also the case at Wilmington Harbor.

The facts and principles just sketched were recognized by the Board of Engineers for the Pacific Coast, and formed the basis of the project which was prepared by it for the improvement of this harbor under the requirements of the river and harbor bill approved March 3, 1873.

The first appropriation for the work was made June 23, 1874. Subsequent appropriations were made in several years, making a total to this date of $355,000; of which the sum of $255,357.19 has been expended, the sum of $99,642.81 remaining available for future use.

Expenditure has thus far been mainly devoted to the construction of the two jetties, which have been extended in, however, an unfinished condition, the north jetty for a distance of 9,500 feet, and the south jetty for a distance of 12,000 feet. These jetties are constructed of loose stone, thrown on the lines and allowed to take its slope, under the action of the waves and currents. They have consumed to the present date 139,213 tons of stone.

The pressing necessities of a rapidly increasing commerce have also required some expenditure for dredging between the jetties in excess of the estimate of the Board of Engineers, as stated in its original report. It has been found necessary to dredge a channel 200 feet wide to a depth of 10 feet, whereas the original estimate contemplated a depth of dredging of only 6 feet for a width of 100 feet. It is even now doubtful whether it will not soon be necessary to increase the width if not the depth, in order to give accommodation to the commerce which is growing rapidly. The total number of cubic yards dredged to the present date is 222,341. The greater part of this material has up to this time been deposited in the deep water of San Francisco Bay. The original estimate for the improvement of this harbor was $1,335,435.20; of which $355,000 has been appropriated.

PRESENT CONDITION OF THE WORK—OPERATIONS OF THE PAST YEAR.

The condition of the channel is 200 feet in width where dredged between the jetties; and in depth for a portion of its length something over 10 feet, and for another portion something less than 10 feet. The original depth after the dredging was completed was 10 feet throughout its length, from which it appears that a portion of the channel has more than maintained its dimensions, while a portion has failed to hold its own. Two careful hydrographic surveys made, one in October and one in March, together with one made at the close of the last fiscal year, illustrate the changes which are taking place in the channel, and also the reasons for these changes. In bringing out the causes, they suggest the measures to be adopted to further the changes which are in a favorable direction and to counteract those which are harmful. A study of the cross-sections of the channel at these different epochs shows a gradual increase of the hydraulic mean depths at the head of the jetties and for a mile or thereabouts outwards; the last survey showing quite a positive improvement. Approaching the outer end of the jetties, there is a distance of about a mile in which the areas of the cross-sections are slowly diminishing. The explanation of these differences is the height of the jetties, which is greater near the shore end; the outer portion having been more beaten down by the waves. In this outer portion more of the tide ebbs and flows over the walls than is the case in the upper part, where the current is more confined within the jetties. As a consequence, it follows that the jetties must be raised.

Another indication which is quite favorable is that the form of the wave has lost in great part the sharpness which characterized it at the beginning of the harbor-improvement and is approaching gradually the normal form.

The operations of the past year were devoted to the extension of the jetties and to the completion of the dredging which was in progress at the close of the last fiscal year. The details of this work are described in the appended report of the assistant engineer on the work, L. J. Le-Conte.

The amount dredged during the year was 13,420 cubic yards. The amount of stone placed on the jetties was 25,162 tons. The north jetty was extended 540 feet and the south wall 960 feet. These operations were terminated by the 1st November, leaving on hand a larger remainder of funds than had originally been anticipated. This remainder was, however, too small to permit new operations to be undertaken with advantage; and, moreover, it was thought that a few months devoted to watching the changes which our previous operations were bringing about would not be lost, but would quite repay delay in giving a sound direction to our next steps. For these reasons it was considered advisable to await a new appropriation by Congress before undertaking new work.

In the mean time a certain amount of supervision over the improvements being made by private parties along the water-front, in seeing that the lines of the wharves and slips were so located as not to do injury to the harbor, and that the dredged material was properly disposed of, together with the studies of the future operations, has afforded occupation to the office.

It will be seen by the report of Mr. LeConte that the Southern Pacific Coast narrow-gauge road has established its terminus on the Oakland harbor-front. This road has or will have its other end at Santa Cruz.

The Central Pacific Railroad Company is also engaged in building wharves and ferry-slips and in large excavations, having in view to make here the terminus of the overland road. If the harbor improvement is continued and the results which are anticipated become accomplished facts, we may look to see a very large commerce in this harbor. The establishment of two different railroad termini here certainly indicates this conclusion, which receives some confirmation in the growth of commerce in the past two or three years.

For instance, the past year shows the gross tonnage of vessels entering the harbor to be 186,640 tons, whereas the amount for the previous year was 114,000 tons. There is also a very noticeable increase in the size of the vessels entering the harbor. The statistics of trade will be found in detail in the appended report of the assistant engineer. Attention is also invited to the fact of the great increase of population in Oakland, which has been more than doubled in the past five years.

FUTURE OPERATIONS.

As has already been indicated, it will be necessary to raise the height of the jetties. They were originally carried up to the height of ordinary high-water, but by settlement, but principally by the action of the waves, they have been lowered to 4 feet above low-water or 2 feet below ordinary high-water. The spring-tides run 2 feet higher than ordinary high-water. The walls must be carried 2 or 3 feet higher. Until this is done, no improvement in the lower part of the channel can be expected. It is a question as yet whether any further dredging will be required during the coming year.

The channel is wide enough for all demands at present, except for those due to two enormous ferry-boats which have begun within the past year to run in the channel. These boats are as large as any of the class known to us anywhere, and perhaps larger. Two of them can hardly pass in a channel of 200 feet width. Moreover, the increase of trade may, independently of the ferry-boats, demand a freer channel.

The legal establishment of harbor-lines has not been brought about. It was hoped that the last legislature of California would take measures to fix these lines, but the measures were not taken. In the mean time certain provisional lines have been established in this office, and parties about to build wharves are informed that, if their constructions are entirely within these lines, no objection will be made; but if they pass these lines, proceedings in the United States courts may be expected in the way of injunction. This appears at present to be the only way in which the integrity of the harbor can be maintained. Among the parties who have accepted these lines as limits for constructions made or in progress during the past year may be named the Central Pacific Railroad Company, the Western Development Company, and the Southern Pacific Coast Railroad Company. The action of these influential parties, without appeal or protest, may perhaps be regarded as giving as great permanence to the lines that have been insisted on by this office as they can have short of their final legal establishment.

Recurring to operations on the jetties, the opinion has been expressed in previous reports that it would probably be necessary to make the portion above low-water of concrete. This will indeed be the best and most permanent construction; but in view of the extra cost and the impossibility of doing the work rapidly enough with the ordinary appropriations, and our further experience with large stones in the riprap work in the past year, it is now proposed to make the inner end of the jetties, at least, of common stone, placed with care. This construction will answer for some years, and will insure the results that ought now to be obtained; and if at some future time, as may be the case, a concrete wall may become necessary, the future can pay for it.

After the jetties are brought to the proper height, and the existing volume of the tidal prism has been fully brought into service, the next operations ought to be directed to increasing the volume, which, it has already been stated, may be done either by excavating the upper part of the basin, or by introducing a fraction of the tidal waters of San Leandro Bay.

Nothing has been made known to this office during the year as to the progress of the suit for condemnation of the land forming the site of the canal projected to unite the two bays.

This harbor is within the customs district of San Francisco. Some statistics of customs collected will be found in the appendix.

The amount of duties received at this port during the fiscal year ending June 30, 1878, was $6,336,314.07.

Money statement.

July 1, 1877, amount available	$62,965 24	
Amount appropriated by act approved June 18, 1878	80,000 00	
		$142,965 24
July 1, 1878, amount expended during fiscal year		43,322 43
July 1, 1878, amount available		99,642 81
Amount (estimated) required for completion of existing project		980,435 20
Amount that can be profitably expended in fiscal year ending June 30, 1880		200,000 00

REPORT OF MR. L. J. LE CONTE, ASSISTANT ENGINEER.

OAKLAND, CAL., *June* 30, 1878.

COLONEL: I have the honor to submit the following report on the progress of the work for the improvement of Oakland Harbor during the fiscal year 1877-'78.

Operations for the past year have been confined to dredging, extending the training-walls, and making examinational surveys.

DREDGING.

On the commencement of the fiscal year the Western Development Company were engaged in fulfilling a contract for 30,000 cubic yards. About 900 feet linear of the southerly cutting remained to be completed. This was accomplished on July 25, 1877, and involved the removal of 13,420 cubic yards. When the above work was completed the said contract was declared as fulfilled and all dredging operations ceased for the year. All the dredged material above referred to was towed away in scows and dumped in 6 fathoms water in San Francisco Bay.

EXTENDING THE TRAINING-WALLS.

At the beginning of the fiscal year work on the walls was going on under a contract with Tilford, Terkelson & Co., for 20,000 tons, at $1.19 per ton. Only about 2,335 tons had been delivered up to the 1st July, 1877. As the contract approached completion, inasmuch as the price per ton and the size of the stone being received were unusually favorable, it was decided to take advantage of the letter of the contract and receive the additional percentage specified. Accordingly, work was continued up to October

31, when said contract was declared to be fulfilled, and all work on the training-walls was suspended.

The total amount of stone received during the fiscal year and expended upon the training-walls amounted to 25,162 tons, which was distributed as follows:

North wall.—Total distance, 540 feet; stone required, 6,783 tons; protecting-piles, 3,108 tons.

South wall.—Total distance, 960 feet; stone required, 10,605 tons; protecting-piles, 4,666 tons.

Grand total, 25,162 tons.

The north wall, as now completed, terminates half way between piles 3 and 4 in the westerly curve, and thus produces a total combined length of 9,800 feet.

The south wall, as now completed, terminates half way between piles 4 and 5, in the westerly curve, thus producing a total combined length of 12,000 feet.

EXAMINATIONAL SURVEYS.

Quarterly surveys and examinations of the navigable channel-way between the two training-walls were made in October, 1877, and March, 1878. The results of these two surveys, when compared, show a general increase both in depth and sectional area of channel-way from pile E, off the "old cribs," easterly and toward the inner harbor; but on the other hand, they show a slight diminution of depth and sectional area of channel-way from pile E out westerly toward San Francisco Bay. Generally speaking, however, the changes taken place have been very slight, considering the very heavy seas that were prevalent during the past winter. Both training-walls have withstood the heavy weather of the past winter remarkably well, more particularly the recent extensions completed last October, which, being composed of larger-sized stone than has heretofore been used, have shown little or no alterations either in height or shape.

GROWTH OF THE HARBOR.

The commercial benefits due to the harbor improvements during the past fiscal year have been very marked and substantial in their character.

The narrow-gauge railroad now being constructed will, when completed, extend from this city via San José to Santa Cruz on the Pacific coast.

This company is now busily engaged in constructing an extensive ferry landing at and near the inshore end of the south training-wall, which structure will constitute the northerly terminus of the said line of railroad, and when completed will be 225 feet wide by 760 feet long; moreover the frontage of the same has been located in due conformity with the United States harbor lines in this locality, as established and fixed by the Board of Engineers for the Pacific coast. This improvement will involve the removal of some 200,000 cubic yards of dredged material, of which amount about 100,000, or one-half, has already been removed.

The material when excavated has been mostly hauled inshore and used for filling in low marsh lands, being transported to its proper destination by means of suitable trains of dump-cars and low motive power. Temporary inclined railways have been constructed along the shelving beach, and allow the trains of empty cars to pass in close proximity to the dredging-machines.

The Oakland Water Front Company constructed and completed a large and commodious wharf at the foot of Market street in this city, and the frontage of the same has been permanently located in strict conformity with the proposed harbor line in this locality.

The Central Pacific Railroad Company is also now engaged in constructing an extensive system of wharves and ferry slips and four large and commodious piers for the accommodation of sea-going vessels. This improvement has, professedly, been designed to constitute and form the westerly end or terminus of the overland railroad, and, when completed, will involve the excavation and removal of some 300,000 cubic yards of dredged materials, nearly all of which is being and will be hauled inshore by means of locomotive power and used for filling in or reclaiming the low, marsh lands along the present city front.

It is with much gratification I am able at last to announce the success of my efforts to bring about this the first definite step taken toward the useful disposition of the material excavated by the several dredging-machines at work in this harbor. There has been great antipathy expressed and general want of enterprise shown in taking the initiative in these operations; but finally the narrow-gauge railroad company agreed to try the experiment, and their success has been so complete that all other parties have been induced to adopt and follow the same plan. I am now quite confident that within a period of three months the old-fashioned dump-scow will be laid aside and all the excavated material will be hauled inshore and used for reclaiming the extensive marsh lands in this vicinity.

For full details of my proposed plan of operations for disposing of all dredged material in the present and future I would respectfully refer you to my report on "A proposed plan for future operations," dated January 29, 1878.

COMMERCIAL STATISTICS.

The following statistics in regard to the growth of the commerce of this harbor and the positive proof that they show of the great benefits which these harbor improvements have been to the general public have been collected and compiled from the best and most reliable sources which the community affords.

An examination into the details of the tabulated results will show the growth of the commercial interests in this harbor to be gratifying in the extreme.

Increase in city and ferry business.

Calendar years.	Population.	Assessment.	Real-estate sales.	Total number ferry passengers.	Total amount collected.
1873	12, 892	$18, 539, 303	$2, 439, 593	2, 655, 671	$306, 235
1874	18, 938	19, 867, 762	3, 042, 371	3, 192, 904	348, 448
1875	27, 043	22, 200, 906	4, 076, 821	4, 028, 310	437, 206
1876	35, 000	24, 000, 718	7, 711, 545	4, 909, 460	524, 312
1877	40, 500	25, 849, 328	9, 128, 495	5, 570, 555	585, 252

Oakland city wharf during 1873, or before any harbor work was begun.

Calendar months.	Number vessels.	Registered tonnage.	Coal.	Wood.	Brick.	Lumber.	Produce.
			Tons.	*Cords.*	*M.*	*M.*	*Tons.*
January	31	808	501	454	59	14	....
February	36	1, 419	1, 257	245	59	59	....
March	25	1, 055	432	140	170	18	....
April	29	981	510	104	104	53	....
May	39	1, 435	1, 000	187	228	60	....
Total	160	5, 698	3, 700	1, 130	620	204	....

During 1878, *or after* 200 *feet of channel was finished.*

January	45	4, 695	1, 694	177	276	841	100
February	84	4, 373	1, 847	234	129	628	110
March	52	3, 546	1, 115	341	293	909	231
April	62	6, 690	2, 457	273	291	1, 766	115
May	48	4, 641	1, 877	123	473	1, 530	117
Total	241	23, 945	8, 990	1, 148	1, 462	5, 674	673

In order to impress upon you still more forcibly the value and extent of the benefits brought about by the late improvements at this harbor, I would respectfully call your attention to the fact that previous to the commencement of these harbor-works vessels drawing 9 feet of water could, when handled by the best pilots in the bay, barely manage to pass over the bar at extreme spring-tides, whereas at present, or since the navigable channel-way has been improved, vessels drawing 16 feet 6 inches can be easily taken into the inner harbor without the assistance of any pilot. Large vessels landing at the city wharf between November 1, 1877, and March 1, 1878, comprise:

	Draught.
1 ship, 1,350 tons register	16′ 6″
1 brig, 495 tons register	16′ 0″
7 vessels, 460 tons register each	15′ 6″
11 vessels, 500 tons register each	15′ 0″
12 vessels, 466 tons register each	14′ 6″
7 vessels, 200 tons register each	14′ 0″

The subjoined table contains a summary statement of the general business at the several wharves owned by private parties along the water-front during the past year:

Number of wharf.	Number of vessels.	Register.	Coal.	Lumber.	Shingles.	Laths.	Brick.	Wood.	Produce.
		Tons.	*Tons.*	*M.*	*M.*	*M.*	*M.*	*Cords.*	*Ton[illegible]*
1	1	280		300					
2	75	20,625		8,000	5,000	1,000			
3	101	20,400		7,000	2,296	924			
4	577	28,850	3,859	813	530	2,570	1,028	255	12,5[illegible]
5	80	2,426	3,600					800	2,5[illegible]
6	829	53,859	25,114	15,473			7,889	3,664	2,5[illegible]
7	1,058	50,200	8,000	9,000	4 000	2,500			
8	25	10,000	13,140						
Totals, 1877	1,768	186,640	45,713	31,586	11,826	4,494	8,917	4,719	17,7[illegible]
Totals, 1876	2,530	114,000	26,748	36,208	13,193	6,355	6,027	4,146	5,2[illegible]

1. Market-street wharf.
2. Merritt's wharf.
3. Taylor's wharf.
4. Foster's wharf.
5. Anderson's wharf.
6. City wharf.
7. La Rue's wharf.
8. Broadway wharf.

In addition to the above statement of the Oakland Harbor business proper, I think we can with propriety also include the present commercial traffic being carried on a the Long Wharf ferry-landing. This entire business will shortly be transferred to Oakland Harbor, and will give rise to considerable increase in the present commercial interests.

LONG WHARF FERRY-LANDING.

Number of foreign vessels arrived	28
Centals of grain exported	624,84[illegible]
Tons of coal imported	59,11[illegible]
Head of cattle shipped	178,26[illegible]

The nearest port of entry to this harbor is San Francisco, distant 7 miles by water, which has a safe and direct communication with Oakland Harbor throughout the entire year.

The following tabulated statement, obtained from reliable sources, will furnish ample proof of the national importance of this port of entry and its bearing upon that of the Oakland Harbor:

Port of San Francisco.

	1876.	1877.
Number of vessels entered	861	9[illegible]
Number of vessels cleared	1,068	1,0[illegible]
Customs revenues	$8,053,000	$8,779,9[illegible]
Exports, merchandise	31,056,200	29,992,3[illegible]
Exports, treasure	49,757,800	57,753,6[illegible]

In conclusion, then, I am much gratified to be able to state that the present improvements at Oakland Harbor are very good, as well as permanent in their character and ability to carry out the purposes for which they were constructed, and, finally, that the navigable channel-way excavated has maintained itself very well during the entire fiscal year.

Respectfully submitted.

L. J. LE CONTE,
Civil Engineer.

Col. G. H. MENDELL,
Major Corps of Engineers, U. S. A.

H H 2.

IMPROVEMENT OF WILMINGTON HARBOR, CALIFORNIA.

The harbor-works and property have been under the charge of a keeper during the past year. In addition to caring for the public property, he has made such repairs as were possible without other assistance. These consisted in stiffening with bracing some portions of the timber line which had been weakened by the attacks of marine insects. He also made some barricades a foot in height for a length of 160 feet along the timber line for the purpose of raising the sand to a greater height. These barricades have proved successful.

The winter just past was unusually stormy, but no permanent injury was done to the works. A breach was made in the sand beach to the seaward of the work, but it was repaired by natural action as soon as the storm was past.

Some changes of importance have taken place during the year, the chief of which is an improvement of 1 foot in the depth of the channel, which was ascertained by a hydrographic survey in the latter part of the year. There is now a depth of 9 feet at mean low-water. Each of the past three or four years has added 1 foot to the depth previously existing. This progress cannot, perhaps, be called rapid, but, on the other hand, it has not been accompanied by any unfavorable symptoms. The increase of depth inside has not thus far involved a decrease of depth outside. The transporting force inside has delivered no more sand outside than the local force at that point was able to carry away. The place of deposit for the material excavated by the tidal forces has hitherto been the westward of the entrance, where a great shoal has been built up. The storms of the past winter carried off a great deal of sand from this shoal, but it is to be supposed that the deposit will again go on as before.

The measure of success which has attended the improvement of this harbor is to be found in the comparison of the original depth at the entrance with the depth now existing. These depths are, respectively, 2 and 9 feet. This increase of depth has been due to natural causes, regulated by the construction of jetties and training-walls. If these forces are to continue to act, the ultimate natural depth has not been reached. Another year will probably add 1 foot to the depth, as several past years have done. The limit of this natural deepening will probably be the depth which has been established by dredging in the reef which lies at the entrance—that is, about 12 feet. Any considerable increase of depth on the reef is not to be expected without dredging, although a recent examination shows portions of the reef to have been washed out several feet during the past year. There are, however, so many stones imbedded in the clay forming the reef that it is hardly probable that this washing out will lead to a practicable deepening of a channel through the reef.

Adding the height of the tide to the low-water depth of 9 feet, we obtain a high-water depth of quite 16 feet at spring-tides and 14 feet at mean high tide. These depths are quite sufficient for the greater part of the vessels which trade at this port, and the sailing-vessel which does not enter the harbor, but discharges at the anchorage outside, is now the exception. The masters of these vessels, who were the noisiest decriers of the improvement in its earlier stages, are now its firmest friends.

There has been little, if any, accumulation of sand outside of the work during the year, except in height over a limited portion. The area covered by the creeping sand-plant has, however, been enlarged, and to this extent the beach has been made permanent.

A portion of the timber line 330 feet in length has been badly attacked by the *Teredo navalis*, which abounds in these waters. About one-half of the length of the stone line forming a part of the main jetty has been flattened by the waves, so that it is now only about 1 foot above mean low-water. The other half has not been lowered to any noticeable extent. The west stone line has also been lowered by the action of storms, and the seaward end, where it was much exposed, has been injured to some extent.

It is to these points that it is proposed to apply the funds available for the coming year, first in protecting 330 feet of the timber line with a wall of large stone on the seaward side; second, in extending and raising the west wall to a height of 3 feet above low-water; third, if the funds hold out, to raise the stone portion of the main jetty to the height of 3 feet above low-water. The amount of the appropriation, which is $20,000, is insufficient for the extent of work which is required on these points.

It is probable that a length of about 1,000 feet more of the timber-work will within a couple of years require to be protected with stone. The cut in the reef, which is now 150 feet in width, ought to be made at least 200 feet wide, with a depth of 12 feet. These items, together with the completion of the stone lines, are necessary before the harbor will be in a condition to be left to itself. The estimated expense of these operations is $100,000, of which $20,000 is now available by the last appropriation. The remainder, $80,000, ought to be given in two appropriations of $40,000 each. So small a sum as $20,000 cannot be applied in the present condition of the work in an economical manner.

The history of this improvement begins with an appropriation of $200,000 made March 3, 1871. This was followed by other appropriations, the last being made at the session of Congress just closed. The total amount appropriated to the close of the present fiscal year is $475,000. The amount expended to the date of this report is $455,000.

The original estimate, which was only for the main jetty, was $400,000.

The cost of the jetty was considerably less than the estimate. A change in the location of the entrance required a considerable amount of dredging through a reef. If it had proved practicable to make the entrance at the point first projected, the work would probably have been completed very close to the original estimate.

This harbor is the outlet to extensive and fertile plains which surround the city of Los Angeles, which is 20 miles distant from Wilmington. The production of these plains are wines, oranges, and other fruits, corn and other cereals. The city of Los Angeles is a prosperous town of perhaps 15,000 inhabitants. The population of the adjacent country has been very much increased in the past few years. Before the harbor improvement was begun, transshipment of exports and imports, as well as of passengers, was made at the anchorage of San Pedro. This anchorage is well covered from northerly winds, but it is open to southerly storms. When these storms came, all vessels at anchor in San Pedro roadstead were obliged to seek safety by going to the open sea. All freight and all passengers were transferred to lighters by a slow and very expensive process. No other course was practicable at that time.

The improvement of the harbor has made it possible for the usual vessels trading at this point to enter a safe, inclosed anchorage, free from all exposure to storms, and to deliver freight without the use of lighters.

While this delivery is possible, the people of the country have not as yet, owing to peculiar circumstances, been able to reap the full benefit which they have a right to expect. The reason why this benefit has not resulted is to be found in conflicting interests of the railroad corporation, which endeavors to force freight to pass over its lines, instead of allowing it to seek the natural and cheapest channel. Owing mainly to the interest of this corporation, which also controls the lighterage system, the greater part of the freight is still subjected to a heavy charge either by lighterage or by being forced over the railroad, when it is perfectly practicable to release it by a judicious use of the facilities which have been created by the United States. The general interest is, in this way, for the time being overborne. This state of affairs must, however, in the nature of things, be temporary. As the population increases and the production of cereals, which cannot bear high freight charges, grows larger, it will be found to the interest of every one, including the railroad corporation, to promote a cheaper exchange of commodities. When this time comes, the full advantage of the harbor improvement will be realized. By community of action it will be practicable to carry freight between San Francisco and Wilmington for perhaps half the rates that now prevail. At this time, special steamers of large freight capacity, drawing 8 or 10 feet of water, will receive and deliver freight on the wharves at or near Wilmington, at a low charge and without the intervention of lighters.

During the past year the steamer Newport has regularly delivered freight on the wharves, and we may hope to see others engaged in the same trade.

Wilmington is in the collection district of San Diego, but it is also a port of delivery. The amount of duties collected at Wilmington on merchandise during the fiscal year ending June 30, 1878, was $13,434.35.

The nearest battery is at San Diego, and the nearest light-house is at Point Fermier, two miles distant.

The number and classifications of vessels which entered the harbor during the year were as follows: Steamers, 53; barks, 2; barkentines, 5; brigs, 5; schooners, 80.

The marine report appended exhibits the trade of the port in some detail.

Marine report for Wilmington, Cal., for the year ending December 31, 1877.

1877.	Steamers.	Schooners.	Brigs.	Barks.	Ships.	Tons of merchandise.	Feet of lumber.
January	22	5	2	......	......	2, 020	1, 321, 000
February	22	11	1	1	......	1, 470	3, 104, 200
March	24	4	1	2	......	3, 701	928, 000
April	20	4	......	......	......	1, 460	945, 800
May	24	7	......	1	1	2, 825	2, 220, 300
June	20	6	2	1	......	1, 557	1, 184, 800
July	16	5	1	......	1	2, 880	2, 090, 000
August	12	20	......	1	......	1, 839	3, 957, 800
September	16	14	1	......	......	1, 255	2, 787, 200
October	16	3	......	2	1	4, 510	719, 000
November	18	2	......	......	1	2, 470	710, 000
December	18	9	1	1	......	1, 118	2, 484, 000
Total	228	90	9	9	4	27, 105	22, 461, 100

CHAS. SEYLER,
Agent S. P. R. R. Co.

WILMINGTON, CAL., *June* 28, 1878.

Money statement.

July 1, 1877, amount available	$943 42	
Amount appropriated by act approved June 18, 1878	20,000 00	
		$20,943 42
July 1, 1878, amount expended during fiscal year		943 42
July 1, 1878, amount available		20,000 00
Amount (estimated) required for completion of existing project		80,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1880		40,000 00

H H 3.

IMPROVEMENT OF SACRAMENTO AND FEATHER RIVERS, CALIFORNIA.

The first appropriation for these rivers was made and expended in 1875. It was devoted to the removal of snags and to the construction of brush-dams, which were applied only to the Feather River. No appropriation has been made since 1875 until the one just passed, which is $15,000, the same as the first. The total is, therefore, $30,000, of which $14,816.15 has been expended, leaving for future use the sum of $15,183.85.

A project has been submitted for the expenditure of this appropriation in removing snags from both rivers, reserving a part for the survey of the lower part of the Sacramento River. It is not at present proposed to construct any groins or other works in the Feather for the purpose of securing greater depth. Such constructions are in most places when they are required necessarily of only temporary benefit and must be replaced each year, perhaps not always, however, in the same position. The amount of trade on the Feather River is hardly sufficient to justify yearly expenditure on this account. Snags, on the other hand, are very formidable obstructions, particularly in the upper part of the Sacramento, and also to some extent in the Feather.

The portion of the Sacramento which is most troubled with snags lies above Colusa. This is a flourishing village, and the outlet of a large and productive country. It is about 100 miles above the city of Sacramento, which is about 50 miles above the mouth. This lower stretch of the river, 150 miles in length, is, as a rule, quite free from snags. The portion of the river above Colusa which is now navigated is about 60 miles. The total length of the navigable channel is therefore 210 miles. In former years, before the railroad was extended up the valley, the river was navigated regularly to Red Bluffs, which added about 50 miles more to the navigable length, making it about 260 miles. This last stretch of 50 miles has such a great fall and so rapid a current that its navigation was always difficult and expensive. No boats have run on this part of the river for a number of years. We may, for present purposes and under present circumstances, regard Walsh's Landing as the head of navigation on the Sacramento. The river from this point to Colusa, a distance of about 60 miles, does not by any means afford what can be called easy navigation. The current is in many places very rapid, shallow bars are frequent, and snags abound. In this part of its course the river changes its bed at will. Each freshet converts acres of high land into river bed, and raises portions of the bed into high bars, which become soon covered with a heavy growth of willows. Each encroachment on the land undermines the large oaks and sycamores, and throws them into the river, where they form dangerous obstructions to navigation. The process recurs annually, and annually snags are removed, so as to permit boats to pass. When the United States do not remove the snags, the owners of boats are obliged to do it under forfeiture of the trade. There is at present no remedy for this state of affairs. If the day shall ever come when the wealth of the country and the interests involved are sufficient to justify thorough protection of the banks, this treatment will end the reign of snags, but until then there is no remedy. An annual expenditure of about $8,000 will clear out enough snags to make a good navigation in the Sacramento to the point named as the head of the river.

This part of the river has been the outlet channel for the main portion of the wheat product. It is not possible to state with any exactness what amount of trade is benefited by this improvement. During the movement of the crops there is quite a fleet of boats on the river, which are withdrawn when the wheat crop is all cleared out. It is estimated that 167,000 tons of wheat were moved by the river in 1876, and it is supposed that the present yield will equal this amount.

There can be no doubt that a limited sum devoted to this purpose will, so long as the river forms the main outlet, be felt as a benefit by a large number of persons engaged in agriculture as well as in transportation.

The lower river, say from the mouth of the Feather, which comes in about 75 miles above the mouth of the Sacramento, presents entirely different characteristics. The middle river, as we may call the portion lying above the mouth of the Feather as far as Colusa, a distance of 65 or 70 miles, although interesting in many respects and indeed extremely important in its relations to the drainage of the country, does not need attention at present so far as its navigability is concerned. This section of the river is interesting from the fact that it carries much less water in floods than either the portion above or below it. This comes about in this way. Not far below Colusa, the river, in its high stages pours over both its banks enormous quantities of water, filling up the low lands on each border, in some places 20 feet deep. The water which escapes over the west bank re-enters the river at Knight's Landing, about 40 miles below its point of escape, while the overflow by the east bank does not rejoin the river until it reaches the mouth of the Feather, 15 miles still farther down. The low lands receive and hold this water during the rising stage of the flood, paying back to the channel during the falling stage. The area of flooded lands on both sides of the river is as much as several hundred square miles. This is the natural state of affairs. Efforts have been made to reclaim, by levees, these low lands, which efforts have thus far failed. If, however, we may anticipate a time when they may be successful, the effect upon the regimen of the river between Colusa and the mouth of the Feather, and the height and character of the floods as they may be affected by these changes, become important subjects of investigation.

The width of the river above Colusa is something like 500 feet, but below the crevasses it is diminished to 250 or 300 feet. The depth, however, is considerably increased below the crevasses, and from here down the banks are permanent and overgrown with willows, which protect them. A flood makes little change here, whereas above Colusa it makes and destroys land with freedom. When the river at Colusa is 5 or 6 feet below its banks the portion of the river for miles below the crevasses is bank-full. The question to be considered is this, namely, if this part of the river is full when the river at Colusa is not within 5 or

6 feet of high-water, what will be the result when the whole river, as it passes Colusa in flood, is confined to the bed below?

The information which we have in regard to the river is not of an exact character, and is, perhaps, hardly sufficient to justify a statement of the problems involved, to say nothing of their solution. The facts which have been mentioned are of a general character, lying on the surface; the data which will be necessary for the solution of these great problems must be ascertained by a detailed study.

At the mouth of the Feather the Sacramento is restored to its integrity. It regains the drainage water which was lost above; it is re-enforced by the tribute brought down by the Feather, which is the largest of its branches, and in consequence its whole physical aspect undergoes a most noticeable change. It becomes wider and more imposing in dimensions, and its water, which in moderate stages above the Feather is clear, assumes a tawny hue, which it retains throughout its lower reach, and which it imparts to the waters of the bays below. The Feather drains 3,400 square miles of area, within which is included, perhaps, the greater part of the placer or hydraulic mines of the State. The washings from these mines give the yellow color to the waters of the Feather, which it imparts to the Sacramento. The American, which enters the main river about 20 miles below the Feather, drains 1,900 square miles of area, and contains within its drainage basin many placer mines, which contribute their quota of color and detritus to the Sacramento.

While no exact records exist of the magnitude of the mining operations, as expressed in quantities of water used or in quantities of material moved, it is yet possible, by averaging such results as have been brought out in the reports of mining engineers and mining companies, to convey, if not an adequate, at least an approximate, conception of their extent, present and prospective.

A miner's inch of water will move, under very favorable circumstances, 8 cubic yards of earth in 24 hours. A movement of 4 or 5 cubic yards per 24-hour inch is not infrequent. The minimum movement known to published records is a little more than one cubic yard per inch in 24 hours. Stated in other terms, and neglecting differences in the estimated quantity of water contained in a miner's inch, these results may be expressed by saying that the maximum movement of earth by water in hydraulic mining is at the rate of 1 cubic yard of earth in 10 cubic yards of water, the minimum being at the rate of 1 cubic yard of earth to something like 70 cubic yards of water. This minimum movement approaches, if it does not touch, the limit which separates profit from loss. The mean movement of earth is probably 4 yards to the miner's inch in 24 hours. We shall be on the safe side to assume the rate at 3 yards of earth to the inch. This assumption means, in approximate terms, that a cubic yard of water will move a cubic foot of earth.

The yearly delivery of water on the San Juan Ridge, lying between the middle and south forks of the Yuba River, which is a tributary of the Feather, is estimated by James D. Hague to be nearly 3,000,000 miner's inches. The same authority places the cubical contents of gravel remaining unwashed in 1876 on this ridge at 700,000,000 cubic yards.

At our assumed rate of movement, namely, 3 yards to the inch, which is entirely too low for this particular district, the yearly excavation by the hydraulic process is 9,000,000 of cubic yards, and, at this rate, something like seventy years would be required to complete the washing of the gold-bearing gravel lying between the forks of the Yuba just mentioned. Whether it shall require this length of time to exhaust these places, or whether, as is generally estimated, it shall require a much shorter time, in either case the magnitude of the operations is a matter of serious concern, when we consider the relation they bear to the drainage-lines and to the lands which lie upon their borders.

This mass of bowlders, clay, gravel, and sand leaves the mining sluices in falling into a river-bed or into a ravine suitable for deposit, or dump, as it is called in miners' language. Here it accumulates during the summer months, when the water is low in the streams. When the winter freshets come, they carry it below. The larger fragments of bowlders find a place of permanent deposit in a short distance; the coarse and fine gravel, the particles of clay and sand, move farther, and come to rest when the force of the current is no longer able to move them. To trace these different materials each to its place of repose, if such a place exists, to ascertain how much goes to raise the beds of the rivers, how much to obstruct the channels, and to build up the shoals in the great Bay of San Francisco, to discover its measure of influence on the heights of floods in the lower rivers, and its effect upon the navigability of the rivers, and to counteract or remedy these evils when determined, is a problem of great complexity, and one in which the great interests of California are deeply concerned.

On the other hand, the relation of mining to the condition of the rivers has a favorable side. The water, which is its main agent, and which is used so profusely, is stored in large reservoirs, which are filled in the winter by rain or by the melting snow in the spring. The effect of this storage is beneficial, as far as it goes, in holding back water which otherwise would flow unchecked to raise the level of floods; and again a beneficial effect is produced on the navigation of the rivers in their low stages, by the restoration of this water to the channels in the summer months. This was quite noticeable three years ago in the Feather, the suspension of mining on Sundays lowering the water about 6 inches, and restoring it upon resumption on Monday.

The navigation of the Sacramento below the city of the same name is more or less obstructed by shoals, which are often the cause of annoyance and delay. The principal shoals are named the Hogsback and Heacocks. The latter is just below the city of Sacramento and the former near Rio Vista, in Steamboat Slough, which is one of two channels into which the river divides a few miles below Sacramento. The river for the whole distance below the city of Sacramento is inclosed by levees, and is subject to overflow in times of flood. Some of these floods are extremely destructive, especially to the reclaimed lands which lie low down the river. The levees have grown up according to the views of the owners of the lands, and sometimes with great errors, both of alignment and of construction.

The lower part of the Sacramento forms, with the San Joaquin, a common delta. The two rivers, one of which comes from the south and drains the great San Joaquin Valley, and the other, which drains the northern part of the State, unite at their respective mouths in the head of Suisun Bay.

In the lower part of their courses they are or have been connected by sloughs or channels extending from one to the other, some of which channels have been closed by owners of adjoining lands in their efforts to reclaim.

No survey of the San Joaquin River has ever been made. The exploring expedition of 1841 made a survey of the Sacramento as high up as Colusa. Since that time there has been no survey of so much of the river. Portions have been surveyed for special purposes, and, in 1850, a map was made of the river as high as Sacramento, under the direction of the Navy Department. A new survey would reveal the changes which have taken place in the past generation, and aid in the solution of some of the problems which have been mentioned as needing attention on this river.

The floods in this river are sometimes excessive. The peculiar climate of California forces the rainfall of a year within the limits of two or three months. The rainfall is sometimes excessive in these months, 15 or 20 inches not unfrequently falling in a month. The drainage area of the Sacramento is, approximately, 28,000 square miles. On some parts of this area the average rainfall is as little as 15 inches, and on others the maximum is as high as 60 or 70 inches.

The distances over which the water has to travel to reach the river are not generally very great, and the indications of the channels are generally steep. On the higher parts of this area the precipitation is mostly in the form of snow, but it sometimes happens that a warm rain brings down suddenly the snow which it had taken days to accumulate. The reclaiming of lands to the sacrifice of the reservoir capacity of the river tends to make the floods more frequent and more severe.

The complications of the mining question add their own difficulties, so that, owing to all these points, life and property along the river are quite unsettled. No one knows how high his levee ought to be, and, as as a rule, the later floods are the highest. All of these questions combine in making this river one of the most interesting studies of the kind that can be found in our country.

It has been stated that the river affords a navigable channel of 210 miles, no part of which requires very expensive works. It is possible to add to this distance 50 miles at the head of the river, and make a navigable channel 260 miles in length, but only at the cost of expensive works, which are not justified by existing circumstances. The part of the river which is really navigable is, however, worthy of attention, and a certain sum of money can be profitably expended yearly.

A survey of the lower river is, next to the removal of snags, the work which most demands attention. Such a survey will fix the position of the bars, and perhaps indicate the proper treatment for their removal.

This river and the San Joaquin are so intimately connected in their lower portions that they ought to be under the same control.

An examination of the Sacramento was made in May of the present year, with the view of ascertaining as nearly as possible the extent of the operations which will be required to remove the snags during the present year.

A similar examination of the Feather River was made for the same purpose, by L. J. LeConte, assistant engineer.

Both rivers on these occasions were higher than the summer stage, and the low-water channels, which change from year to year, were not fully defined, so that those estimates of the extent of operations can only be regarded as an approximate basis for contracts. The low-water stage of the upper river begins in August, and sometimes in July, and ends with November or December. This period is the working-season of the year, and if the snags are not well out of the way in August the necessities of commerce are not met. These circumstances in this particular year, when the appropriation is made so late in the season, urge to great promptness of action in getting the river ready for its duty in time for the movement of the crop.

The estimated amount of this crop has been stated to be 167,000 tons of wheat. The quantity of wheat moved on the Feather is estimated to have been last year 6,760 tons.

There are at times two boats employed in trade between this city and Marysville. They are necessarily of light draught, for the Feather in its summer stage does not carry more than 2 feet on its bars. When any considerable amount of freight is carried, it is placed on barges, which are towed by the steamers. Other boats make special trips as required during the movement of the wheat crop.

One of the brush dams which were built in the river in 1875 remains, and has done good service; the others were washed out in the high-water. The bed of the river is so shifting that we can hardly expect any such structures as it would be justifiable to build to have much permanence.

Under these circumstances, any regular treatment of the river to secure, say, 3 or 4 feet of water in the low stage, must be repeated each ear, and then only for the convenience of a small trade for two or three months, at the end of which time the water rises.

Regular work of this kind each year is not thought to be demanded by the extent of the trade existing on the river. When a special case occurs which gives promise, by treatment, of making a lasting cure, it may be well to build the necessary dams or groins, but the ordinary routine of improvements on this river ought to be confined to the removal of snags, of which there are not many in the Feather.

These rivers are within the customs-district of San Francisco, and the nearest forts and light-houses are those in San Francisco Bay. The duties on imports in the last fiscal year amounted to $6,336,314.07.

In closing this report it may properly be stated that an investigation of the river problems outlined in the preceding pages has been undertaken by the State engineer of California, under authority given at the last session of its legislature. This survey will go over much of the same ground that a survey for simple river-improvement would do, and by co-operation on the part of the United States the essential facts which ought to be known in order to project a system of improvement can be obtained at a cost to the general government much less than would be required in an independent effort to obtain these facts. It is, therefore, thought that co-operation with the State will be a judicious policy.

Money statement.

July 1, 1877, amount available	$243 25	
Amount appropriated by act approved June 18, 1878	15,000 00	
		$15,243 25
July 1, 1878, amount expended during fiscal year		59 40
July 1, 1878, amount available		15,183 85
Amount that can be profitably expended in fiscal year ending June 30, 1880.		**20,000 00**

APPENDIX II.

ANNUAL REPORT OF LIEUTENANT-COLONEL C. SEAFORTH STEWART, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1878.

UNITED STATES ENGINEER OFFICE,
San Francisco, Cal., July 3, 1878.

SIR: I have the honor to transmit herewith annual reports for the year ending June 30, 1878, of the river and harbor works in my charge.

Very respectfully, your obedient servant,

C. SEAFORTH STEWART,
Lieut. Col. of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

II 1.

IMPROVEMENT OF THE HARBOR AT SAN DIEGO, CALIFORNIA.

On the 14th of October, 1877, a sudden and very heavy fall of rain, due, it is said, to a cloud-burst, caused some damage by washing holes at several points in the embankment of the levee between Presidio Hill and Point Loma Peninsula. Repairs were made as soon thereafter as possible, before the setting in of the rainy season. It is reported that during the past winter more rain fell than at the time of the heavy floods of 1873–'74, and that the flood-waters were carried off without injury to the works by the new artificial channel-way. Thus far the construction has proved a success.

An examination of the levee was made in May, 1878. In a few places it is found that the water, during the rains of the past winter, which fell on the top of levee, in draining off had formed holes, which must be refilled during the present dry season. This is likely to take place each year, and to keep the embankment in fair repair will probably require a yearly expenditure of some $300. A small outlay in time will avoid a heavy expense at a later day. I would, therefore, respectfully ask that an appropriation of $1,000 be made for the ensuing fiscal year, to be applied to repairs of this work as needed.

FINANCIAL STATEMENT.

Appropriated by act approved March 3, 1875	$80,000 00
Amount expended during fiscal year ending June 30, 1875	1,669 26
Available July 1, 1875	78,330 74
Amount expended during fiscal year ending June 30, 1876	4,148 25
Amount available July 1, 1876	74,182 49
Amount expended during fiscal year ending June 30, 1877	73,980 75
Amount available July 1, 1877	201 74
Amount expended during fiscal year ending June 30, 1878	133 52
Amount available July 1, 1878	68 22

This improvement is situated in the collection-district of San Diego, which town i the nearest port of entry.

Point Loma light is the nearest light-house.

The work begun at Ballast Point is the nearest fort.

The amount of revenue collected at San Diego during the past fiscal year is given a $5,102.35.

Money statement.

July 1, 1877, amount available	$201
July 1, 1878, amount expended during fiscal year	133
July 1, 1878, amount available	6
Amount that can be profitably expended in fiscal year ending June 30, 1880, and succeeding years, for repairs	1,000

I I 2.

IMPROVEMENT OF THE SAN JOAQUIN RIVER, CALIFORNIA.

To find out how much work should be done to improve the navigatio of this river below Stockton, William P. Smith, assistant engineer, wa ordered, August 13, 1877, to make a survey of the narrows from Stockton Slough to the outlet of Burns's Cut-off, and lower if necessary. He reached Stockton with his party on the 22d of the month, and finishe work in the field on the 3d of September.

The general results of the survey are given in my letter to the Chie of Engineers, under date of September 26, 1877. The plan of improvement adopted was to cut away about 100 feet in length from the extremity of each of the points of land opposite the sharp bends near th outlet to Burns's Cut-off and at the Devil's Elbow, giving a depth at th parts cut away of 6 feet at the low stage of water in the river; then t dredge the approaches to the same points and remove some shoal spo between them and Stockton Slough, and at the outlet to the latter, t the same depth.

Proposals for doing this work were invited by advertisement Octobe 17, 1877, to be received until noon of November 21. At that hour non had been made nor any inquiry as to the work to be done. The ne day persons called for information, saying they thought a later day ha been fixed for the reception of the bids, though they had seen and re the advertisement. Therefore, on the 28th November, proposals w invited by circulars until noon of December 6. One was received at t hour named, the rate given being $1 per cubic yard of material r moved and deposited on the bank of the river. The bid was rejected too high. Proposals were again asked for until December 8. On th day two bids came in, one formal the other informal; the former, at cents per cubic yard, was the lower, and was accepted as the best th could be had.

Contract was entered into with the bidder, John Hackett, of Oakla Alameda County, California, to do the work. He began on or ab the 27th of December, 1877, at the point opposite the outlet to Bur Cut-off, and ended satisfactorily about two weeks within the cont time, on the 17th April, 1878, at or just below the outlet of Stoc Slough. The material removed was placed on the banks of the ri The amounts were as follows, viz: At Burns's Cut-off, 5,638 cubic ya at the Devil's Elbow and vicinity, 10,890 cubic yards; near Nap Gardens, 1,491 cubic yards; at and near outlet to Stockton Slo 4,994 cubic yards; total, 23,013 cubic yards.

After completion of the dredging, another survey was made, to see what changes had taken place where excavations had been made.

While work was going on, the river was at a high stage from the winter rains, and some deepening had taken place at the points at the Devil's Elbow and opposite Burns's Cut-off, and some filling below these points, also at places where shoals had been removed to make the passage easier for boats. This filling in again, from the character of the shifting sand overlying the true bed of the river, was expected, in a greater or less degree, but the general result of the improvement has been to aid boats in passing the worst bends.

It is intended, if possible, to have a new survey made of the same part of the river at the low stage of water this summer, to find out what the action of the currents during the entire year since the preliminary survey of 1877 may prove to be.

It is reported that the number of round trips of river-steamers between Stockton and San Francisco, during the year 1876, was 488; of sailing-vessels, 284; during 1877, of the former class, 511; of the latter, 308. Total registered tonnage in 1876 of all vessels above referred to was 158,721; in 1877, it was 196,326 tons.

FINANCIAL STATEMENT.

Amount appropriated by act approved August 14, 1876	$20,000 00
Amount expended during fiscal year ending June 30, 1877	6 80
Balance in Treasury of United States July 1, 1877	18,000 00
Amount in hands of officer or subject to his check July 1, 1877	1,993 20
Amount expended during the fiscal year ending June 30, 1878	19,363 29
Amount available July 1, 1878	629 91

This amount will complete existing project.

The work done is believed to be in the collection-district of San Francisco.

The nearest light-house is at Mare Island.

The nearest forts those in San Francisco Harbor.

San Francisco is believed to be the nearest port of entry.

The amount of revenue collected at San Francisco during the past fiscal year is reported as $6,336,314.07.

Abstracts of proposals and of contract are forwarded herewith.

Money statement.

July 1, 1877, amount available	$19,993 20
July 1, 1878, amount expended during fiscal year	19,363 29
July 1, 1878, amount available	629 91

Abstract of bids for improving San Joaquin River below Stockton, California, opened December 6, 1877.

Name and residence of bidder.	Nature of work.	Price per cubic yard.	Remarks.
T. C. Walker, Stockton, Cal	Dredging	$1 00	Rejected as too high.

Abstract of bids for improving San Joaquin River below Stockton, California, opened December 8, 1877.

Name and residence of bidder.	Nature of work.	Price per cubic yard.	Remarks.
John Hackett, Oakland, Cal	Dredging	$0 69	Formal, and bid accepted.
T. W. Walker, Stockton, Cal	....do	70	Informal.

Abstract of contract for dredging on the San Joaquin River below Stockton, California.

Contractor.	Residence.	Date of contract.	Subject of contract.
John Hackett........	Oakland, Alameda County, Cal....	Dec. 11, 1877	Dredging 21,000 cubic yards more or less, from the Sa Joaquin River, California

I I 3.

CURRENT-OBSERVATIONS IN SAN FRANCISCO HARBOR, CALIFORNIA.

SAN FRANCISCO, CAL., *July* 19, 1878.

SIR: By letter of February 15, 1877, the survey for military defen of a part of the harbor of San Francisco, Cal., asked from the Chief o Engineers, United States Army, by the Board of Engineers for Fortifi cations, under date of February 12, 1877, was put in my charge.

It proved that recent surveys by the Coast Survey in this harbor gav enough data, so far as soundings and shore-lines are concerned, and a tracing giving the latest details was forwarded for the use of the abov Board to the Chief of Engineers, with letter of March 31, 1877.

First Lieut. A. H. Payson, Corps of Engineers, was charged with th work of getting needed data as to velocities of currents. All credit fo the details and for the work done is due to him.

The greatest velocity found was about 7 feet a second. His report i transmitted herewith, also a card of samples of wire and lines used i making current-observations. A separate roll, containing three tracing lettered A, B, and C, respectively, and seventeen sheets numbered fro 1 to 17, inclusive, which are referred to in the report, is sent by mail.

Very respectfully, your obedient servant,

C. SEAFORTH STEWART,
Lieutenant-Colonel Engineers.

The CHIEF OF ENGINEERS, *U. S. A.*

[First indorsement.]

OFFICE CHIEF OF ENGINEERS,
Washington, July 27, 187

Respectfully referred to the Board of Engineers for Fortifications. be returned to this office when the Board is through with its use.

By command of Brigadier-General Humphreys.

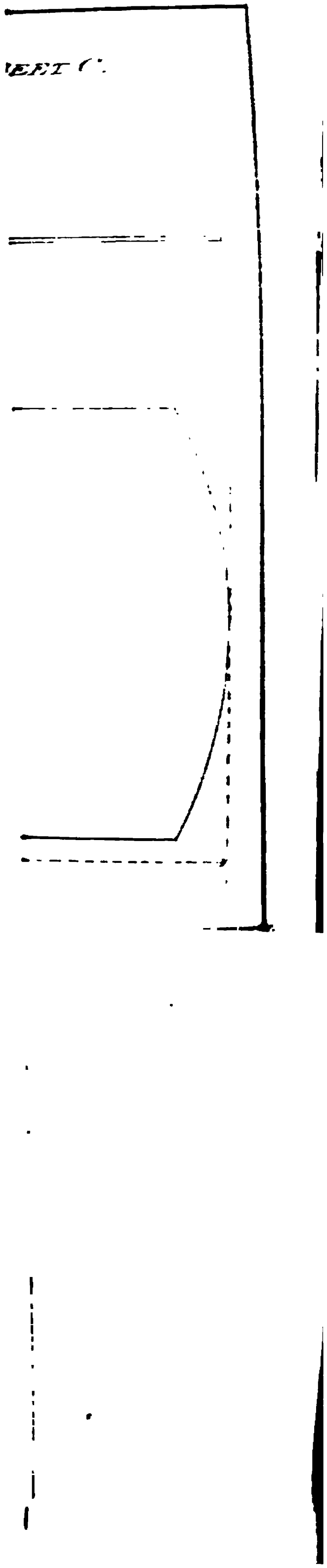
H. G. WRIGHT,
Lieut. Col. of Engineers, Brt. Maj. Ge

REPORT OF LIEUTENANT A. H. PAYSON, CORPS OF ENGINEERS.

SAN FRANCISCO, CAL., ———, 18

COLONEL: Having, in compliance with your instructions, made a series of cu observations in this harbor, I have the honor to submit the following report wi accompanying tracings, sheets of velocity, curves, &c.

The schooner Alcatraz having been secured for the purpose, work was begun ber 15, 1877, and finally discontinued April 24, 1878. That the results in the w plotted observations are so incommensurate with the time used in collecting them due to several causes, of which the chief was the very unfavorable weather. ordinary seasons calm days are quite common from October to the fore part of D ber, the interval between the end of the westerly summer winds and the winter



EET C.

During the past year, however, up to the 1st of January, there were not more than four or five occasions when work could be carried on all day, while after that it rained almost without cessation to the end of February, and the summer winds followed immediately the end of the rains.

Moreover, as it was impossible to rely on placing the vessel at her station in the morning, she had to be left on it all night, which caused much time to be lost in getting to and fro. Considerable time also was spent in various experiments; and, finally, quite a large number of can-observations, taken under the most favorable conditions, were rejected altogether.

In the beginning, the main reliance was on the double cans, on account of their convenience in practice and because they had been used before in all the observations in this bay. The meter was tried with them, but as an auxiliary about whose usefulness there was much doubt, under the rough conditions to which it would necessarily be exposed. After a certain amount of data had been collected with each and an opportunity obtained for its reduction and comparison in the office, it was found that the indications by the two methods differed so much as to virtually contradict each other. It was plainly useless to go on with both, and necessary to resort to some third means of measurement to decide between them.

For this purpose the "free floats" were chosen. The experiments are described hereafter, but some of the comparisons made with the meter, floats, and cans are plotted on sheets Nos. 3 and 4, and a reference to them will show the reasons for the conclusion reached to abandon the use of the latter. From the fore part of December to the last of January work was chiefly done with the floats, since the prevailing southerly swell almost entirely prevented the meter's use; but afterward, and to the end of the observations, the latter was alone employed. I was directed to confine myself to the shoalest water "between Point San José and Alcatraz Island, between Alcatraz and Angel Island, on a line crossing Raccoon Straits, and on a line between Alcatraz Island and the shore between Yellow Bluff and Saucelito."

Since the object was mainly the maximum velocity which might be expected, I thought it best to occupy most of the time in the main channel-ways, without, however, wholly restricting myself to them. The stations actually taken are shown on the tracing marked A. The sheets contain only those days' observations which were considered complete enough for plotting. Nos. 5 to 10 are meter-curves; Nos. 11 to 16, free-float; while No. 17 contains cases of can-curves, selected to show their characteristic difference from the others.

Meters.—For trial, I was furnished with two meters of a form devised by General Abbot, Corps of Engineers, for use in salt-water. They were precisely alike, and will be understood by a reference to Fig. 1, sheet C.

A B represents the axis of a Woltmann wheel. It revolves within a water-tight brass box, shown in cross-section, its bearings being at B and in the packing-screw C. D is a brass standard, insulated from the outside of the box by vulcanite, represented in the darkly-shaded portions of the drawing. The axis passes through without touching a hole in this standard. E F is a flexible copper contact-spring, borne on the top of the standard, which, at one extremity, presses on the terminal, E, of an insulated copper wire, and at the other on the raised sleeve of platinum, F, secured upon the axis. This platinum sleeve has sunk into its surface a narrow band of agate, so placed that during one-half revolution of the axis the end, F, of the contact-spring presses on the agate, and during the other half upon the platinum. G is a packing-box, through which the insulated wire is brought; M, an opening to admit air while filling the inside space with oil, and N another for oiling the bearing C. K is a socket, with a clamp-screw in its side, for the insertion of a "Jacob staff," and L the fish-tail, by which the instrument is kept in the thread of the current. The working of the meter is as follows: One pole of the battery goes to earth through a copper plate hanging in the water, while the circuit from the other is led through the recording apparatus, and, by insulated wire, to the end, F, of the contact-spring. During that half revolution, while this end bears upon the agate, no current passes; during the other, the circuit is opened through the axis of the wheel and outside of the box to ground.

Battery.—The battery was formed of four cells, with zinc and copper plates, each about 16 square inches in area, separated by 4 inches, the space between filled with about one-third of a pound of blue-stone for each cell, and sand. It was used for six months, during that time giving no trouble and requiring no attention beyond the occasional adding of some water.

Recording-apparatus.—The recording-apparatus was a Morse sounder of the simplest form, the beats of its armature being counted from minute to minute while observing.

The pitch of the meter-wheel was so low that this could be done without difficulty up to the maximum velocities found; while this method has the advantage over any automatic system of recording, that, while listening to the sounder, any irregularity of the meter's motion is at once detected.

It is precisely like having the instrument always in your sight. The best manner of placing the meter at various depths was a subject about which I was in considerable doubt. The proper way, under ordinary circumstances, is to have a heavy weight on the bottom, from this to plumb a rope or wire to carry the instrument and take up the oscillations of the water's surface by a spring-pole or counterpoise at its upper end. But in San Francisco Harbor the variations in direction of the surface-currents are so excessive and follow each other so rapidly that this plan would have been impracticable from a vessel ordinarily anchored, while the depth of water is so great that it did not seem possible, with the means at my command, to secure the fixed position which is absolutely necessary. I therefore decided to suspend the meter with its weight clear of the bottom and trust to the smoothness of the water's surface for the accuracy of its record. The objections to this method would have been nearly, if not quite, done away with had my instruments been, with their wheels, like that of an ordinary wind-gauge, with hemispherical cups revolving about a vertical axis, so that they could not have been checked by any slight vertical motion. In practice it was found that a pretty stiff breeze did not much affect the meter-observations, since the schooner remained comparatively steady, but a swell always forced me to stop work with it.

The weight used was a leaden ball 9 inches in diameter, weighing in water a little over 150 pounds. This was suspended by a No. 16 (Birmingham gauge) wire of English tempered steel, with a diameter of .065 inch. A specimen of this wire was tested by me before use, and broke with 725 pounds. The same wire, kept constantly well oiled, was used throughout the observations, and afterward a piece from the working end stood 713 pounds before parting, showing that its strength had not been impaired by the weight it had borne, nor by the intense vibration into which it was thrown when sunk in a rapid current. The attachment of the wire to the ball is shown in Figure 2, sheet C. The steel rod A B hooked into a ring on the ball, while its other end screwed into a steel box, B D, and against the heads of two steel wedges, E and F, which worked in a wedge-shaped slot. The end of the wire being placed between these wedges, they were tightened by screwing up the rod, and any pull afterward only made them grip the closer. By this means the full strength of the wire was made use of, since it was not weakened by any turn. At C two shoulders were brazed on the rod, of a proper size to enter the Jacob-staff socket of the meter and allow it to turn freely on them.

Above the water the wire passed over an iron swiveled sheave, 18 inches in diameter, hung on the main boom, and then to a heavy reel bolted to the deck. A second or preventer wire was permanently fastened to the ring of the ball, and thence, when the meter was in use, was led forward to the bow of the schooner, where it was hauled in and made fast at the proper point to bring the suspending wire vertical. When the apparatus was made, I did not believe the meter would slide up and down the wire in a swift current without a downhaul line and block at the ball. So at first it was put permanently at the point C on the rod and placed at the required depth by raising or lowering the ball. But the labor and time necessary for this and the proper setting of the preventer, led to its being put free on the suspending wire, as follows:

A leaden cylinder was made, of the same diameter as the socket of the meter and weighing about 8 pounds. This had, bored along its axis, a hole just large enough to allow the wire to slide freely in it.

To the top of this cylinder was attached a strong fishing-line; to this the insulated wire, from the meter up, was stopped every ten feet, and at each stop was a brass ring, which inclosed the suspending wire to prevent too much bowing out. The ball having been first placed near the bottom and hauled to the proper point by the preventer, the meter and its weight were easily raised or lowered by the line, and the depth determined by the stops, whose distances apart were verified by frequent remeasurement. At the outset the mistake was made of trying to occupy too many depths. This, and the labor of setting, rendered the first observations of little value, owing to the distance apart in time of points in the same velocity-curve.

Coefficient.—The methods of finding the coefficient of a meter are, 1st, to draw it at a known velocity in still water; 2d, to allow it to revolve a certain time in water of a known velocity. The formulas used have generally been of the form $v = cn + a$, in which v is the velocity, n the number of revolutions, and a that velocity at which the meter-wheel ceases to turn.

In those forms of meter where the number of revolutions is registered by a train of wheel-work, the value of a will be considerable, but in an electrical recording instrument, whose bearings can be made of any required delicacy, it may be rendered almost inappreciable save for very low velocities. The above formula is probably never theoretically correct, the law of change in the coefficients being more properly expressed in a curve. In meters having a high pitch, and which consequently increase their number of revolutions very rapidly for small changes in velocity, this curve can be discovered, and from it tables of coefficients formed for computation. But where the instrument is of a low pitch, or, in other words, less delicate, this curvature in the law of coefficients becomes, within the limits of usually observed velocities, so slight as to be masked by the errors made in observing for it. For experiment, I had prepared a float, shaped like a boat at the ends, and of sufficient size to carry the meter, a battery-cell, and bell struck by an electro-magnet. The meter was carried on an iron tongue, in front of the float and 5 inches below the water's surface, each of its revolutions producing a stroke of the bell. The float was dragged in a pond at velocities varied as much as possible, and a determination of the constant made for each observation. A second series of experiments was made in a flume at Fort Point.

A perfectly straight portion, 100 feet in length, was measured and its velocity carefully determined by a large number of observations with subsurface floats, made of small bottles, submerged till their centers of figure came at about the depth of the meter axis. The meter, placed midway in the measured portion, had its revolutions counted for 15 minutes; after which it was drawn at various rates up against the current and allowed to float down with it, its motion more or less checked.

Finally the flume velocity was again determined as before. These observations are plotted on sheet No. 1. No. 1 is the one with the meter stationary in the flume, unquestionably the best individually. Nos. 2 to 14, inclusive, were in the pond; the remainder with the meter moving up and down the flume. As will be seen, the results are not close enough to show any curvature, and are well agreed with generally by a right line through the origin and a mean of all. These experiments were made with only one instrument, a careful comparison in the flume having shown the other to be precisely like it.

During the observations in the harbor, the wheel of one meter was lost by working loose in the water. After the completion of the field-work, the constant of the other was tested by a very careful trial with it stationary in the flume.

The results are as follows:

Mean of observations of July and August give	.03721
Meter stationary in flume, August, gives	.03705
Meter stationary in flume, April, gives	.03697

Formula.—The formula used in practice was:

$$v = .0372\ n,$$

in which

$v =$ velocity in feet per second;

$n =$ number of revolutions per minute.

The meter was counted from two to five minutes, and the velocities taken from a table computed by the above formula. That the results were sufficiently exact, with velocities from 1 to 6 feet per second, is shown by their close accord with simultaneous observations taken by other means. Below 1 foot they are uncertain; while below .5 of a foot the meter is useless, on account of its low pitch.

During work in the bay, a deflection of the suspending wire was occasionally noted. When the meter-constant was verified in April, 1878, an attempt was made to determine the retardation of the meter's motion, caused by its being at an angle with the current.

The results are plotted on sheet I, the abscissæ being the natural tangents of the angle, the ordinates the fractional part of the indicated velocity, which must be added to get the true. These results are peculiar. The retardation increases about uniformly till we reach an inclination of 18°. From this on to 26°, the number of revolutions per minute was not appreciably affected; thence the retardation again increased uniformly to 45°, at which point the wheel ceased turning altogether. The behavior of the instrument between 18° and 26° was so singular, that it was verified by several successive trials.

Cans.—At first, use was made of double cans of the form and size before employed in this harbor. They were cylinders of galvanized iron, 6 inches in diameter by 12 inches long; the upper one ended by a cone 6 inches in height.

After they were found unreliable and given up, others were made on the model of those used in the United States Coast Survey, and with them a series of experiments was carried on, which will be described hereafter. They were also cylinders of galvanized iron; the lower can 11 inches by 13 inches, with its top formed by a cone 6 inches high; the upper one the same size, but coned at both ends. The sizes of line used in connecting and logging are shown in the card of specimens. In use, the bottom can was wholly or partly filled with gravel, the upper left empty or with sufficient water in it to make the combination sink to the base of the upper cone. The detached surface-can was weighted with water to make it float in the same position.

Theory.—The theory on which observations with the double cans are based is that the combination will move with a velocity which is a mean of those of the surface and subcurrents, since it presents the same cross section to each. The influence of the connecting cord is disregarded and it is supposed stretched to its full length.

Having noted the velocity of the connected cans, with the lower at a given depth, and made a separate but simultaneous determination of the surface-velocity, we deduce the subsurface rate as follows, in the case of both currents being in the same vertical plane:

same time integrates a series of varying ones. This would affect the agreement of individual measurements, though, in a large number, these discrepancies might be expected to balance. From the table it will be seen that the meter and float confirm each other very well, while both show a large excess over the cans.

To get some idea of the relation between the can error and velocity, the meter and floats were regarded as practically the same, and all the observations collected into groups. The first group included all velocities under 1 foot per second; the next those under 2 feet, and so on to the highest obtained. The mean for the cans in each group was then subtracted from the mean for the meter and floats in the same, and the corresponding percentage of error deduced. A series of points was thus found, approximately, 1 foot per second apart in velocity, from which it appeared that the proportion of error decreased from 30 per cent. for velocities below 1 foot per second, to 14 per cent. for those between four and five.

This great retardation must chiefly be due to the log-line, which appears large for its purpose, but was taken because of the same size as the one which had always been used before. In logging with the greatest care, it is almost impossible to strike the exact mean between checking the line and paying it out too fast. The former is the more obvious error, and, in the attempt to avoid it, the latter is almost certain to be committed, in which case the line sinks in a bight, whose weight exerts a constantly-increasing pull against the motion of the can. This effect was so marked in feeble currents, say less than 0.8 foot per second, that the can was often brought by it to a complete standstill, when only 50 or 60 feet from the vessel's stern. Finally, any ripple or sea will retard an object moving on the surface, while the meter and free floats were beyond its influence; the former being submerged about 2 feet and the latter, a large paint keg, supported by its tin cylinder at the same depth. Whatever the cause, it is certain that with the methods used, the can surface-velocities were far too small, while, in the application of either of the formulas, this error is directly introduced with the effect of increasing the computed subsurface by itself.

Suppose, for instance, the velocity at the surface to be 6 feet per second, the same at 10 feet depth, and that the can gives the surface velocity 5.5 feet. By formula the subsurface will be $V^d = 2\ V^c\ V^s$, or $V^d = 12 - 5.5 = 6.5$, and we shall have found that instead of the velocities being equal they increase 1 foot in going from the surface to 10 feet in depth. It must be remembered that owing to the greatly superior weight of the connected cans, their motion could not be checked by equal causes in anything like the same proportion as the surface, can alone.

If the fault in the surface-measure was the sole cause of the discrepancy, for which an explanation is sought, we might expect that a mean vertical-velocity curve, as given by the cans, would show an abrupt increase from the surface to the first depth, and thence a gradual variation to the bottom, following the general law for subsurface change, as given by the floats and meter. To ascertain whether this was so or not, there were plotted for all the days' observations, by each method, the velocities at each depth as ordinates, with corresponding times for abscissæ, to a scale large enough to show minutes of time and hundredths of a foot per second. The points for the same depth were then joined by right lines, and the velocities in each interpolated for each 6 minutes in time. For every day's work a mean of all these interpolations was then taken for each depth and these means plotted as abscissæ, on a scale showing thousandths of a foot, to ordinates indicating depth.

These points being joined by right lines gave a mean vertical-velocity curve for the day. In each of these mean daily curves, the velocity for each tenth of depth was interpolated; and finally, these last interpolations, weighted for the number of observations which went to form the curve, were combined for each method, and their means taken, giving a grand mean vertical curve for meter, floats, and cans. These are plotted on sheet No. 2, Figs. 1, 2, and 3. In order to compare them, since the actual velocities are different, the abscissæ in each are reduced to surface-velocity as unity by dividing, and the resulting curves plotted over each other in Fig. 4. The co-ordinates for all of these are given in Table II.

TABLE II.—*Co-ordinates of mean vertical curves.*

Depth.	METER. Each point mean of 322.		FLOATS. Each point mean of 993.		CANS. Each point mean of 379.	
	Abscissæ.		Abscissæ.		Abscissæ.	
	Real.	Reduction to surface.	Real.	Reduction to surface.	Real.	Reduction to surface.
Surf.	2.626	1.0000	3.404	1.0000	2.499	1.0000
1	2.663	1.0102	3.393	.9967	2.737	1.096
2	2.699	1.0277	3.377	.9921	2.935	1.175
3	2.666	1.0152	3.341	.9815	3.016	1.207
4	2.620	.9977	3.301	.9697	3.100	1.240
5	2.556	.9733	3.253	.9556	3.174	1.270
6	2.459	.9364	3.194	.9383	3.283	1.314
7	2.418	.9207	3.136	.9213	3.333	1.334
8	2.339	.8907	3.059	.8987	3.478	1.392
9	2.197	.8366	2.986	.8772	3.367	1.348
10	2.047	.7795	2.912	.8554	3.431	1.373

The depth "1.0" denotes the nearest multiple of 10 feet above the bottom.
No velocities used less than 1 foot per second.

A reference to the figures shows that both meter and free-float curves, though somewhat unlike in form, agree in showing a gradual decrease from the surface downward; while with the cans precisely the opposite occurs. In the former, moreover, the large number of which each point is a mean has been enough to cause the irregularities to balance each other and produce a nearly true curve; while with the latter this is not at all the case. It becomes necessary, therefore, to seek for other causes of error than the deficient surface-measures given by the cans.

For this purpose the second and larger kind described before was used. They were purposely made the same in every particular, even to the connecting and logging lines, as those used by the Coast Survey here and in Puget Sound.

The following are some of the points which suggest themselves for attention:

1st. The chance that in spite of the increased size of the surface-can and its small log-line, it yet gave a false measure of surface-velocity.

2d. In a majority of cases the surface and deep sub-currents make an angle with each other. The connected cans will then move across the surface-current, while their log-line, lying in and moving with it, will be swept into a bight and the recorded velocity of the combination increased.

This effect had been often noted, and experiments were made to get some idea of the possible amount of the resulting error and the frequency with which it might be expected to occur.

3d. The supposition that the connected cans move with a velocity which is a mean of those of the two currents in which they may be, regards as inconsiderable the effort of intermediate ones on their connecting cord; in other words, is not theoretically correct, since there must be some effect from this cause. If we enlarge the connecting cord to the diameter of the cans, or make the combination a weighted tube, it will move with that velocity which is a mean of all acting on it from the surface to its base; and, whatever be the size of the cord, there will be acceleration whenever this mean exceeds that of the surface and sub-currents, and retardation when the reverse is the case. Attempt was made to discover whether the result was appreciable in practice.

4th. A horizontal impulse cannot be transmitted from one can to another of a combination while the connecting cord is vertical. Should there be any difference in velocity between surface and sub-current, the cord tries to take the position of the resultant of this difference, and the weight in water of the bottom can; and the latter will be raised above the point it is supposed to occupy into a probably swifter current.

This effect, though increased by the bowing of the line, cannot be large, and there seemed no way for its measurement. It was done away with, as far as could be, by making the bottom can as heavy and the connection as fine as possible.

Finally, there are two other errors, which, though not inseparable from the method, and always to be avoided with proper care, may be mentioned here as very likely to occur in practice.

They are, first, the sheering of the vessel from which the observations are taken while the log-line is running out; and second, failure to give the connected can's log-line sufficient spare, so that the first "mark" is given while they are yet rushing forward to their bearings.

First experiments; large surface-can.—For a check on surface-can and meter a third measure of surface-velocity was used.

This consisted of a wooden pole, weighted at the bottom so as to stand upright in water, and immersed about 5 feet. It was logged, but with so fine a fishing-line that it seemed impossible for it to have any retarding influence.

The observations were taken during 11 days, under various conditions of wind and tide, and are given in full, Appendix A. The results are in the following table:

TABLE III.—*Large surface-cans, meter, and pole.*

	Pole and can.		Meter and can.		Meter and pole.	
	Pole.	Can.	Meter.	Can.	Meter.	Pole.
Number of observations	138.	138.	140.	140.	118.	118.
Total	410.73	370.01	399.53	363.59	347.92	353.59
Mean	2.971	2.681	2.854	2.596	2.948	2.997
Difference in favor of	.290		.258			.049
Per cent. error		.0976		.0904		

From this it will be seen that meter and pole agree in their testimony to a considerable error in the surface-can. That this error has two components, surface agitation and the log-line, there can be no doubt; but it is impossible with the data to separate them, since most of the observations were necessarily taken with the water too rough for accurate work. Whenever the wind and sea tend in the direction of the tide, they will accelerate the can's motion and partly or wholly counteract the retardation caused by its vertical oscillation. Some idea, however, of wind effect, when against the tide, may be formed from the last 16 operations of March 30.

Up to the first of these the sea was calm and the agreement between the different methods good. A fresh breeze against the tide then sprung up, making some sea, though not enough apparently to affect the pole or meter.

These are the results:

Meter total, 52.88; meter mean, 3.305; excess meter, .636.

Pole total, 52.39; pole mean, 3.274.

Can total, 42.70; can mean, 2.669; excess pole, .605

By meter the cans are in error 19 per cent., by pole 18¼ per cent.

As a further illustration of the general accordance of the meter with other reliable surface measures, from Tables I and III a mean of all observations with free floats and pole was taken and compared with the simultaneous readings of the meter, with the following result:

Total, 242 observations; float and pole, 692.64; mean, 2.8621.

Total, 242 observations; meter, 693.21; mean, 2.8645.

It must be remembered that the velocities actually measured and varied from $\frac{6}{10}$ of a foot to 6.2 feet per second.

2d. Subsurface log-line.—In the experiments bearing on the second point, the can-surface record was discarded and the pole-measure only used in computation. The subsurface can was set at 50 feet, the greatest depth the station afforded, and loaded with gravel to weigh 16¼ pounds in water. In every observation the connected cans and pole were allowed to run for 30 seconds, and the angles their courses made with each other carefully noted with a sextant, close attention being also paid to the appearance of the log-lines.

The meter was read for at least two consecutive minutes, beginning before and ending after the outrun of the pole and cans. The results are given in full, Appendix B. They were separated into two classes, the division being entirely independent of the agreement between the methods. Class I, or "good," included every case where there was no remark in the note-book that the connected can log-line had been bowed, nor that the operation was untrustworthy from some other cause.

Class II, or "bad," rejected also the untrustworthy ones and was formed of those where a bowing of the line was noticed and where the angle between the course of the combination and surface-current was equal to, or more than, 10°. It included, consequently, nine of Class I. A summary is in the following table:

TABLE IV.—*Meter and subsurface cans.*

	Class I.—"Good."		Class II.—"Bad."	
	Meter.	Subsurface cans.	Meter.	Subsurface cans.
Number of observations	77	77	85	85
Total	159.18	169.21	189.75	267.54
Mean	2.067	2.197	2.231	3.147
Difference in favor of		.130		.916
Per cent	6.3		41.	

It will be seen that out of 153 cases occurring on ten different days, 76, or 50 per cent., were visibly affected by this cause of error; and so largely as to give rise to an average excess of more than 40 per cent. in the computed velocities by the cans over the readings of the meter. With the "good" observations, this discrepancy falls to near 6 per cent.; but since, even in these, the divergence varied from one to nine degrees, it is fair to attribute some of the difference to that cause, though a bowing of the line was not actually noted.

There is, however, another point to be considered. The meter-ball was generally lowered during slack-water, and the suspending wire plumbed by the preventer. When the tide became strong, with the meter lowered to full depth, its action upon the wire and suspending cord caused a visible bowing of the former, with a consequent raising of the fall and inclination of the meter-axis to the thread of the current. This inclination could not, of course, be actually measured, though that of the wire could, and was whenever seen, but never found larger than 7½ degrees.

Granting the deflection of the meter-axis to have been the same, reference to Fig. on sheet 1, shows a corresponding reduction of its indications of between 4 and 5 per cent. The mean-meter-velocity from Table IV, is 2.067 feet per second; $2.067 \times .05 = 1.033 - .067 + 1.03 = 2.170$. Hence, even this extreme supposition does not give a complete explanation, the mean can-velocity being 2.197. It may suggest itself that the meter might have been additionally retarded by the vessel's motion; but, during all the experiments, it was frequently run at the surface, for comparison with the pole, so that any such effect would have been detected if appreciable. I conclude, therefore, that some, and probably the larger portion, of the difference between the meter and "good" can observations, may be laid to the axial deflection, but that it cannot justly be charged with all.

3d. *Effect of connecting cord.*—Two sets of cans were prepared for comparison. The first was the same as those before used, with the connection rope, the bottom can weighing about 16 pounds in water, and the top one partly filled to make the combination float properly. The second had its top can empty, bottom one weighing 50 pounds in water; while the two were joined by the same steel wire used for hanging the meter. Theoretically, then, the second was the nearer perfect set, the connection and its probable deviation from the vertical being reduced to a minimum. At the word "mark," time was taken, the schooner's stern located by sextant angles, and both sets of cans let go over it, side by side. They were followed in a boat, their position fixed by sextant as often as possible, and corresponding times taken. Three tests of this sort were made on two consecutive days. The various points were then carefully plotted and velocities deduced. The courses of the cans are shown on the tracing marked "B," and the results collected in the following table:

TABLE V.—*Wire and rope connected cans.*

	April 1—a. m.		April 1—p. m.		April 2—a. m.	
	Wire.	Rope.	Wire.	Rope.	Wire.	Rope.
Start	$9^h 05^m 38^s$		$12^h 43^m 00^s$		$10^h 17^m 30^s$	
Interval to station 1	$17^m 07^s$	$19^m 12^s$	$15^m 05^s$	$19^m 58^s$	$5^m 40^s$	$7^m 13^s$
Velocity	2′.13	2′.33	2′.21	2′.34	[2′.51	2′.02]
Interval to station 2	$13^m 29^s$	$10^m 34^s$	$41^m 03^s$	$26^m 24^s$	$19^m 30^s$	$14^m 55^s$
Velocity	2′.22	2′.61	[3′.14	0′.94]	2′.67	3′.03
Interval to station 3	$11^m 44^s$	....	....	....	$10^m 58^s$	$10^m 42^s$
Velocity	2′.56	....	....	....	1′.60	2′.47
Interval to station 4	....	....	....	....	....	$22^m 13^s$
Velocity	....	....	....	....	....	1′.90

NOTE.—Intervals mean time taken in coming from preceding station; velocities in feet per second, and are actual, not computed, subsurface.

Not only do the two combinations show that they are not alike affected by the currents in their tendency to diverge, but they indicate also decidedly different rates. The excess is in favor of the rope, save in two cases, inclosed in brackets in the table. In the first of these, the rope combination dragged on the bottom; in the second, the cans were located so quickly after being dropped that a slight error in position would have largely affected the velocity. The best comparison is afforded by the paths taken on April 2, between stations 1 and 2. The two sets moved in parallel courses, quite near each other, and during about simultaneous times. The rope exceeded the wire by .36 feet per second. In every case, at the start, the rope took the lead. To test the point still further, the two combinations were logged together during parts of three days.

The operations are given Appendix C.

In 66 comparisons the wire was in excess 39 times, by a total of 19.59, and the rope 27 times, by a total of 9.29. There seems here a marked tendency for the wire to go faster than the rope. I think this accounted for by the weather. During two of the days there was a good deal of wind and a chop sea; with much disturbance of the water's surface it seems likely that the heavy wire combination would beat the light rope, the former moving through or under the waves in the full force of the surface-current, while the surface-can of the latter is rising and falling, much of the time only half submerged, or actually lying on its side. This view receives confirmation from the fact that, on the last of the three days, when all circumstances were exceptionally favorable, the discrepancy is again quite marked the other way. Out of 18 observations the rope was in excess in 12, by a total of 4.61, and the wire in 6, by a total of 1.60. It is quite evident, therefore, that in whatever direction it may be, there is generally quite a large difference between the two sets in their indications, both of the course *and velocity* of the subcurrents.

A few comparisons of the heavy wire-connected cans, with the meter at 50′, were made, the former being allowed to run out free and picked up astern, like the free floats, to avoid the inaccuracies of logging. The results are in the following table. There is a little better agreement than between the meter and "good" logged cans.

TABLE VI.

	Meter and free cans	
	Meter.	Free cans.
Number of observations	43.	43.
Total	64.39	6[illegible].65
Mean	1.498	1.5[illegible]
Excess		.0[illegible]
Per cent	.05	

Summary.—Finally, to sum up the whole matter, it appears to have been shown—

1st. That in can operations, as they have ordinarily been taken, there has been a large deficiency in the measurement of the surface-velocity, and that this deficiency has, by the formula, been introduced directly into the computed subsurface-velocities, increasing the latter by itself.

2d. That in the determination of the rate of the connected cans there have been two sources of error always present and inseparable from the method, namely, the bowing of the log-line in the surface-current, and the effect of the connecting cord.

3d. That of these two the first is far the more important, and acts always to increase the recorded velocity of the combination.

4th. That the second, though uncertain and probably small in amount, has the same tendency in a majority of cases.

5th. That the probability of the first occurring, and the effect of the second, increase directly with the depth.

6th. And, finally, the weakest point of the whole method is that these and all other mistakes arising from bad logging, wrongly-measured angle, &c., are, by the formulas, *doubled* in the computation of the required subsurface-velocity.

With a true surface-measure, large, heavy, and finely connected cans, and proper means for getting their true outrun, I have no doubt that good results can be obtained: but, in practice, from causes above stated, I believe the cans to have been often so much in error as to indicate the precise reverse of truth.

Pointer.—The greatest drawback to the meter is that it gives no clew to the direction of the subcurrents, which, unless some auxiliary means can be devised for that purpose, would restrict it usefulness to rivers beyond the influence of tide. To discover whether this defect could be supplied, and at the same time test the angles given by the can formula, the following apparatus was employed:

A rod, 50 feet long, was made of ⅜-inch iron gas-pipe, in sections of 10 feet each: these sections so bolted together that a twist at the joints was impossible. At the bottom was a rudder of sheet-iron, 18 inches square, and at the top, in the same plane, a long pointer. When in use, the rod, with a 50-pound weight attached to its foot, was hung in the water from a swiveled block, carried on a beam which projected about a foot from the stern. Just above the rudder and on the middle section were two thimbles sliding freely, and around these were bent the ends of two preventer-wires by which the whole arrangement was plumbed. During observation, the angles made by the direction of the pointer with those of the surface-pole and 50 feet subsurface combination, were carefully noted.

Rejecting those cases where the cans were logged, in which the results were visibly affected by the bowing of the line, we have 122 comparisons given in Appendix D. A summary is in the table.

TABLE VII.—*Angles by pointer and can formula.*

Direction of difference.	No. of cases.	Sum of angles.	Mean angle.	
		°	°	
Pointer to formula.....	60	833	14	"Pointer to formula" means that pointer was to right of direction given by formula.
Formula to pointer	62	813	13	"Formula to pointer" the reverse.

Causes of difference.—Though these differences nearly balance each other, they are individually large. The explanation for them is to be sought from two sources, first, the twisting of the pointer out of the plane of the rudder, from the bowing of the rod; second, error in measurement of the angle from pole to subsurface combination.

Test for first point.—The first question was tested as follows: The rod was hung in one of the angles of the fort at Fort Point, and the pointer exactly adjusted. The rudder having been directed to a distant station on Alcatraz, the rod was bowed till the middle perpendicular to its chord equaled 4 feet, and in four different planes, namely, that of the rudder and Alcatraz and those making angles of 45, 90, and 180 degrees with it. The deflection of the pointer in each case was carefully read with a transit.

In only one instance (90° plane) did the angle reach 5 degrees; varying in the others from one to two. Since it is hardly possible that, with the precautions taken, the rod could ever have been bowed as much as this in practice, five degrees must be taken as the maximum error chargeable to this cause.

Second point.—Owing to the construction of the formula, a small change in the measured angle will sometimes make a very large difference in the computed one. The corrections necessary to apply to these measured angles to make the pointer and formula coincide were determined for each of the observations and are shown in Appendix D. The results are in the table.

TABLE VIII.

	Correction +	Correction –	Note.
Number of cases..........................	58	61	Three of the 122 observations rejected because taken in nearly slack water.
Total	263°	280°	
Mean	4°.5 +	4°.5 –	

It will be seen that the corrections are about as often positive as negative, and that the average one is only a little more than four degrees. When the connected cans are let go, they first rush forward some distance till they have reached their bearings, and only then start on their true course.

Moreover, probably neither they nor the pole ever go out in a straight line. The result is, that, in taking their angles just before they are stopped, the observer only gets the best possible approximation to their desired mean direction, while he measures even that from an eccentric position. Under these circumstances, a mistake of four degrees does not seem at all unlikely to occur; while the probability that it actually did is increased by the closeness with which the positive and negative corrections balance each other. From the facts, then, that an error in the measurement of the angle is almost certain to be made, and that such error, though small, causes a large one in the results of the formula, I am of the opinion that the pointer, at least to the depth of 50 feet, gives the much more reliable indications of the two.

Object of vertical curves.—The general velocity curves, whose co-ordinates are given in Table II, were not deduced with the idea of trying to find an expression of the general law of change from the surface down, but merely as a graphical illustration of the differences between the three methods of measurement. To arrive at the first result would seem impossible in an ever-varying tidal flow, complicated still further by the daily pouring in of large quantities of water from the rivers.

No matter of how large a number our curve was a mean, it would yet represent nothing which could be said to exist, since the velocities used to form it would not have been found in the same plane. It was thought, however, that some difference might be found between the flood and ebb tides, and as the largest number of observations had been taken with the free floats, they were used for experiment.

The resulting curves are plotted on sheet 2, Figs. 5, 6, and 7, and their co-ordinates given in the following table:

TABLE IX.—*Flood and ebb tide curves.*

Depth.	Flood (each point mean of 235).		Ebb (each point mean of 742).	
	Actual abscissæ.	Reduced to surface-velocity.	Actual abscissæ.	Reduced to surface-velocity.
Surface	1.1106	1.0000	3.592	1.000
.1	1.1114	1.00007	3.573	.995
.2	1.1143	1.00030	3.544	.986
.3	1.1010	.9913	3.507	.976
.4	1.0843	.9763	3.467	.965
.5	1.0664	.9602	3.419	.952
.6	1.0555	.9504	3.347	.931
.7	1.0434	.9395	3.277	.913
.8	1.0174	.9161	3.213	.894
.9	.98693	.8887	3.144	.875
1.0	.95638	.8611	3.073	.855

It will be seen that the ebb-tide curve shows the velocity as decreasing all the way from the surface; while the flood indicates a slight increase from the surface down to between two and three-tenths the depth. The amount of this change from the surface to the bottom is also greater with the ebb than the flood curve. Some such result might have been expected from the discharge of the rivers, with its tendency to re-enforce the surface ebb and check the surface flood. A comparison of the general curves shows the meter as differing from the floats in two particulars. It locates the point of maximum velocity at a point about two-tenths the depth below the surface, instead of at it, and shows a more rapid rate of decrease between seven-tenths the depth and the bottom.

Since the operations on which they are based were not simultaneous, and the float curve is a mean of a much greater number, a complete agreement was not to be expected; yet the variation seems more marked than it should be. A great predominance of flood-tides in the meter-observations might have given a partial reason; but such was not found to have been the case.

It is possible that some of the meter's increase in the first two-tenths of the depth may have been due to its position at the surface, which was perhaps affected by the vessel's wake. But the main boom, from which it was hung, was guyed out over the side to avoid this effect; while the almost perfect accord between the meter and other surface-measures has been shown before. Explanation for some of the difference in the bottom velocities is to be found in the probable deflection of the meter's axis, when suspended at considerable depths.

When used together, under ordinary circumstances, the meter and floats agreed quite well, as will be seen by a reference to the simultaneous observations given in Appendix E, and summarized in the following table:

TABLE X.—*Meter and free floats.*

	CLASS I.		CLASS II.		CLASSES I AND II.	
	Floats.	Meter.	Floats.	Meter.	Floats.	Meter.
Number of observations	64.	64.	96.	96.	160.	160.
Total	162.91	168.44	239.95	236.34	402.86	404.78
Mean	2.545	2.631	2.499	2.468	2.518	2.529
Excess		.086	.031			.011

Class I includes all observations at less depth than 50′. Class II includes all observations at greater depth than 50′.

The excess is in favor of meter for less depths than 50 feet and of the floats for the greater depths, but the discrepancies are not large, the individual results follow each other quite closely, and between the means for both classes there is a very trifling difference. These comparisons were made in November, when the rivers were quite low, and were then thought so satisfactory that, being much troubled by swell, the meter's use was given up for a time and work carried on solely with the floats. In January, after long and heavy rains, observations were begun in Raccoon Straits, under circumstances which rendered them untrustworthy. Through this place the first flood and ebb currents do not run directly, but entering it at a rather sharp angle are reflected twice from one shore to the other. In the middle of the tide their course is tolerably straight through the passage, but later, toward the change, they are again bent back till it is sometimes hard to distinguish between the last currents of one tide and the first of its successor. Moreover, when the rivers are very high, the surface ebb will begin while below it is yet strong flood, and, conversely, the young flood is making up along the bottom long before the surface ebb has ceased to flow. As the result of all this, the horizontal layers of water begin to go through their cycles of change in direction at different times, and it becomes possible to find, in the same vertical, currents varying in direction with each other from zero to 360 degrees.

Under these conditions it became impossible to use the floats. Not only were they continually lost by fouling on the anchor-chain or meter-wire, but, when they moved out at a large angle with the surface-current, they could not be made to pass under the pole, nor picked up by the boat astern.

These were difficulties connected with the method of using and not chargeable to the floats themselves, but, under these abnormal conditions, the surface-tin would often be dragged along on its side, with only the tip of its flag out of water, or seen sometimes completely pulled under and the combination lost. The meter was therefore substituted during the rest of the observations.

Sheets of velocity-curves.—Among the plotted sheets of velocity-curves, the most interesting are those taken with the meter during the floods in March and April, 1878, since they exhibit, in a marked way, the irregularities thereby caused. For this reason they were not used in the deduction of the general vertical velocity-curves.

Strong ebb.—March 15 and 16, station 41, sheet No. 10, are good examples of a strong ebb, with great excess in the surface-current, due to its re-enforcement by river water.

Flood.—April 6, station 45, sheet No. 10, is a characteristic flood. There is to be seen at its beginning a sudden leap up of the surface-velocity, while in less than an hour later we find it falling and remaining below all the subcurrents, till, toward the end of the tide, it is nearly slack, while there is yet a flood-velocity of nearly 3 feet per second at 60 feet in depth. The first-mentioned circumstance was a phenomenon often noticed while the rivers were in flood. When the surface-ebb runs long after the flood has made underneath, the surface flood-currents become backed up as it were, and come in finally in a sort of bore, making a well-defined line upon the water. When this line passed the vessel, the velocity would sometimes change, within a couple of minutes, from zero to 4 feet per second.

Change from ebb to flood.—March 9, station 38, sheet No. 9, is a change from ebb to flood. It was low-water at Saucelito, quite near the station, at 9.30 a. m. At 10, the flood-currents had begun to make at 40 and 60 feet in depth. Increasing rapidly, at 1 p. m. the 40-foot curve had reached about 4 feet per second, while there was yet an ebb of nearly 1 foot per second at the surface. At 1.36 p. m., the surface became slack, and after remaining so 50 minutes, began to run very slowly flood at 2.24 p. m., nearly 5 hours after the time of Saucelito low-water, and when the day's tide of 2.3 feet had reached within three-tenths of a foot of its highest level. One hour and a half after this it was high-water at the gauge.

During this day, therefore, the surface-flood was nearly obliterated.

Slack 20 feet.—March 11, station 38, sheet No. 9; on this day a very remarkable thing happened. The tide rose continually from 10.45 a. m. of the 11th to 4.30 a. m. of the 12th, 17 hours, changing its level in that time 4 feet. Nothing of the kind had ever been observed before in the harbor; but it occurred again during the following 24 hours, March 12 and 13. The velocity-curves for the day are peculiar; but their most striking feature is the layer of slack water, which was found between 2.23 and 3.18 p. m. at the depth of 20 feet. When it was first noticed that the meter would not work at that point, though showing strong flood-currents above and below, the matter was further tested as follows: A free float was thrown for that depth and remained nearly stationary, though slightly influenced by the upper velocities. A bit of sheet-lead, nearly a foot square, was lowered to 20 feet by a silk thread; the thread hung vertical, though on being raised or lowered 10 feet, the plate tailed out with the strong flood. This condition of things lasted about an hour, and was so frequently vertical that there can be no doubt of its actual existence.

About half an hour before this began the 40-foot curve also shows a period of slack or nearly slack water.

Continuous meter-curve.—On sheet No. 1 is shown a continuous meter-curve for one hour, at 60 feet in depth, the readings being plotted for each minute. It is curious in showing a succession of pulsations, the duration of each being about 16 minutes. As an illustration of how rapidly changes in velocity follow each other, there will be noticed in one case an increase of 1 foot per second in 2 minutes.

Change in tide.—When, under the influence of tide, water flows in or out of an estuary, the central portions lose their motion last, and changes from flood to ebb or ebb to flood begin inshore. This is a well-known fact, the reasons for which are plain. It seems natural to suppose that, for similar causes, these changes would precede in the layers of water nearest the bottom, in those cases where there was no disturbing inflow from rivers. Confirmation of this was found on two occasions, during the earlier observations, when there was little doubt that the change from flood to ebb began at the greatest depths, though the interval between the first flow there and at the surface was very slight.

As the rivers rose, however, this tendency of the turn to begin near the bottom was greatly exaggerated for the change from ebb to flood and reversed for that from flood to ebb, till we reached the extreme case of the surface-flowing ebb through nearly the whole of the two tides.

Maximum velocity.—The chief object being to find the maximum velocity which might be expected in the localities mentioned in the order, attention was mainly given to the strength of the tide in places where such velocities would probably be found.

Though more than 40 stations were occupied, the bulk of the work was done in the close neighborhood of four principal points, namely: midway between Black Point and Arch Rock, in the deepest water between Shag Rock and Angel Island, in Raccoon Straits and the channel near the Saucelito shore. In all these places, save Raccoon Straits, velocities of 6 feet per second were not uncommon during spring ebbs. The highest velocity found at any time occurred on February 28, at station 38, where, during the latter half of an ebb, the velocity went to 7 feet per second at the surface. This was a sudden gush of water, however, the rate being maintained for only a few minutes and then falling to less than 5 feet.

Seven feet, then, may be taken as about the maximum; though it is possible that a flood in the rivers, a very high spring tide and the previous backing up of water in the bay by continued westerly winds, might combine to slightly surpass it.

In conclusion, I give my preference to the meter for use in places like this harbor where work cannot be done from shore. Under circumstances which render all methods but approximations, it is certainly as good as, if not the best, of any; while in the ease with which it may be managed, and the rapidity with which it accumulates data, it has greatly the advantage over either floats or cans.

Respectfully submitted.

A. H. PAYSON,
First Lieutenant of Engineers.

Lieut. Col. C. S. STEWART,
Corps of Engineers.

APPENDIX J J.

ANNUAL REPORT OF MAJOR JOHN M. WILSON, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1878.

UNITED STATES ENGINEER OFFICE,
Portland, Oreg., July 1, 1878.

GENERAL: I have the honor to transmit herewith annual reports upon the river and harbor works under my charge for the fiscal year ending June 30, 1878.

I am, general, very respectfully, your obedient servant,
JOHN M. WILSON,
Major of Engineers, Brevet Col. U. S. A.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

J J 1.

IMPROVEMENT OF THE LOWER WILLAMETTE AND COLUMBIA RIVERS, FROM PORTLAND, OREGON, TO THE SEA.

As the various difficulties to be encountered in opening the channel for deep-draught vessels from Portland to the sea have been enumerated in my previous reports, and a plan for the improvement of this stretch of navigation has been approved by the Chief of Engineers, it is not deemed necessary to repeat this description.

OPERATIONS DURING THE FISCAL YEAR.

The annual summer freshet in the Columbia, which backs up the water in the Willamette, reached its maximum at Portland, 14.1 feet above low-water, on June 18, 1877, and then began slowly to recede.

On August 1, the river being 9½ feet above low-water, the United States dredge was sent to the mouth of the Willamette where extensive filling had taken place during the high-water in the Columbia. The work of dredging was commenced August 6, and continued until August 23, during which period 5,730 cubic yards of sand were removed, and a channel 100 feet wide and 17 feet deep at low-water was opened. On August 24 the dredge started for Swan Island Bar, reaching there Saturday evening, August 25, and after careful soundings, on Tuesday, the 28th, the work of dredging was commenced. Operations were continued here until September 15, during which period a depth of 16 feet at low-water was obtained through the channel by removing 5,075 cubic yards of sand, mud, snags, sticks, gravel, &c. This dredging was difficult and unsatisfactory, and the bucket was badly broken, requiring extensive repairs.

SAINT HELEN'S BAR, COLUMBIA RIVER.

Considerable changes having taken place in Saint Helen's Bar, and vessels not being able to carry a draught of over 15½ feet across, a the channel for that draught being narrow and crooked, the dredge was ordered to that place and reached there September 17, 1877. Work was commenced on the 18th, and continued with more or less interruption from breakage, &c., until November 8, when it was suspended for the season. During this period a channel was dredged through the bar, 600 feet long and 110 feet wide, with a depth of 19 feet at low-water, by removing 14,320 cubic yards of sand.

This channel was immediately used by vessels navigating the Columbia, and beacons were erected with targets for ranges by day and lights for ranges by night. Operations were suspended for the season on November 9, and the dredge towed to winter quarters and crew discharged on the 15th. On the 12th, 13th, and 14th, by authority of the Chief of Engineers, the dredge was used by the Oregon Steam Navigation Company, who paid all her expenses during that time.

The following dredging has therefore been done during the fiscal year ending June 30, 1878:

	Cubic yards.
Removed from Swan Island Bar	5,075
Removed from mouth of Willamette	5,730
Removed from Saint Helen's Bar	14,320
Total	25,125

The time actually employed was as follows:

	Working days.
At Swan Island, from August 28 to September 18	17
At mouth of Willamette, from August 6 to August 23	16
At Saint Helen's Bar, from September 19 to November 8	44
Total	77

Of these 77 working days of 10 hours, there was time lost from breakage, hauling out for passing vessels, &c., as follows:

	Days.
At Swan Island Bar	3.2
At mouth of Willamette	3.7
At Saint Helen's Bar	16
Total	22.9

The average amount excavated during the 77 working days was 326 yards per day of 10 hours, against 278 yards per day of 8 hours last year. The average amount excavated while actually working was 466 yards per day of 10 hours, against 362 yards per day of 8 hours last year.

SURVEYS DURING THE YEAR.

Resurveys have been made during the year at Swan Island Bar, Post-Office Bar, mouth of Willamette, and Saint Helen's Bar, and permanent bench-marks established. Observations for volume and velocity were taken at Swan Island Bar.

These continued surveys and examinations are rendered necessary by the constant changes occurring at the various bars. The freshets in the Willamette and Columbia Rivers produce diametrically opposite results at Post-Office Bar and the mouth of the Willamette; those from the former scour out, while those from the latter fill up the channels at those places. The freshets in the Willamette fill up the channel at Swan Island, and the freshets from both rivers fill up that at Saint Helen's.

FRESHETS IN 1877-'78.

In March, 1877, the Willamette and Columbia rivers rose rapidly, and for the first time, as far as the records show, simultaneously, the

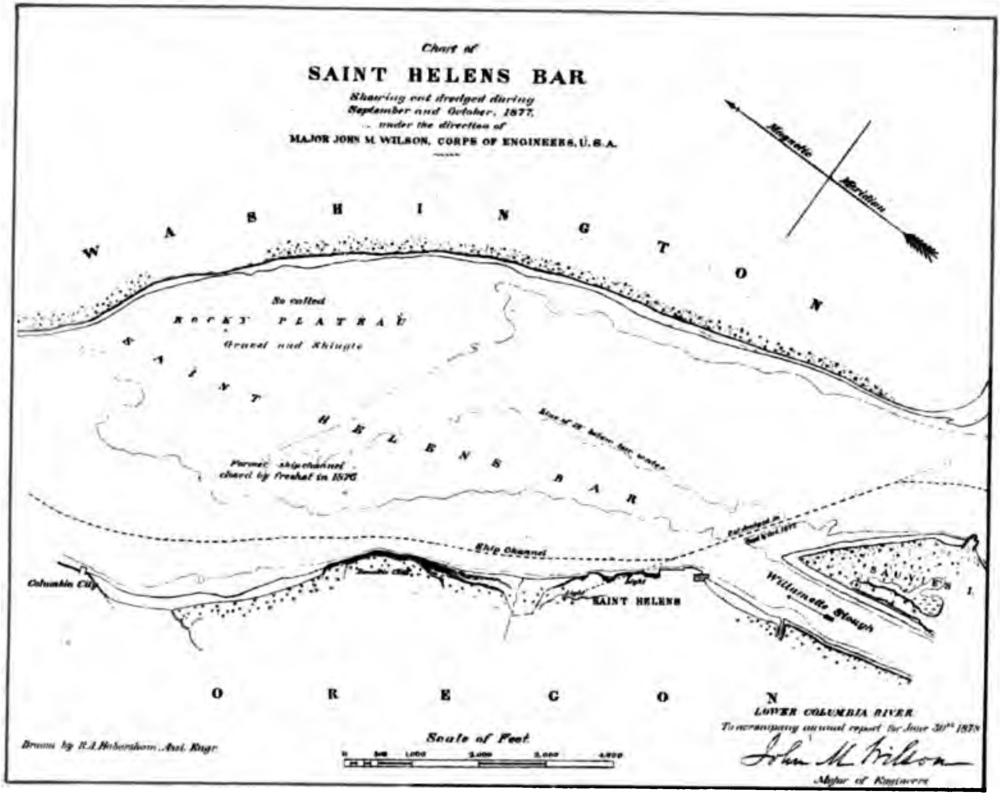


Chart of

SAINT HELENS BAR

Showing cut dredged during
September and October, 1877,
under the direction of
MAJOR JOHN M. WILSON, CORPS OF ENGINEERS, U.S.A.

LOWER COLUMBIA RIVER
To accompany annual report for June 30th 1878
John M. Wilson
Major of Engineers

Drawn by R.J. Habersham, Asst. Engr.

river at Portland being 19 feet above low-water on March 16. This freshet rapidly subsided, and on May 5 reached a level of 5 feet above low-water. The Columbia again commenced rising, the Willamette above the falls still falling, while below the Columbia freshet backed up the water. This freshet reached its maximum at Portland, 14.1 feet above low-water, on June 18, being just one-half the height of the freshet of 1876. From June 18 the water began slowly to recede, reaching 6 feet above low-water August 25, exactly the same height as on that date the year previous. The Willamette continued to fall until October 3, when a level of 2½ feet above low-water was reached. The rains then began to swell the tributaries and it slowly rose, reaching a height of 14.2 feet on November 26. It then commenced falling again, reaching its lowest level, 1½ feet above low-water, on January 7, 1878. Heavy rains again caused it to rise, and on February 6 it was 12½ feet above low-water. About this time the Snake River commenced rising, and, pouring its volume into the Columbia, raised that river, and thus held up the water in the Willamette, which kept up to 11 feet above low-water until February 22. Cold weather coming on in the mountains the rivers rapidly fell, the gauge at Portland reading 4¾ feet on March 15. At this time the freshet in the Willamette had exhausted itself. The Snake again began to rise, and the river at Portland was backed up to a height of 11½ feet by March 30. From this time it begun falling, reaching a height of 6 feet by the last of April, which it maintained until May 11. The Upper Columbia then began to rise, and the annual summer freshet reached its maximum of 14¾ feet above low-water June 15, 1878. It then slowly fell again, the gauge on June 30, 1878, reading 12 feet above zero.

SNAG ISLAND BAR, COLUMBIA RIVER.

This bar presents a depth of about 15 feet at mean low-water, with two tides daily of from 6 to 8 feet. It is thought that by scraping the depth can be increased, and this will be tried during the coming year.

BAR AT THE MOUTH OF THE COLUMBIA.

No survey has been made during the year of this bar. A succession of violent gales during the winter of 1877-'78 has slightly shifted the line of deepest water in the south channel, and the beacons on Sand Island have been moved accordingly. There is still a good wide channel with a depth of 20½ feet at mean low-water in the south channel, while the north channel presents a depth of not less than 4 fathoms. There are two tides daily with a rise of from 7 to 9 feet. I still adhere to my statement made in my last annual report, namely, that this bar has an undeservedly bad reputation, and that if properly buoyed, except when violent southwest gales are blowing, the occasions are rare that a vessel cannot cross in safety. I respectfully recommend that a careful resurvey with current-observations both on the flood and ebb be made of this bar during the coming year; the months of July and August are the best to conduct the survey.

SURVEY OF SAND ISLAND, MOUTH OF COLUMBIA.

The annual survey of Sand Island was made in May, 1878, and showed very extensive changes. These annual surveys have been made since 1868, with the exception of the year 1875, and a constant change has been going on in the shape and position of the island. These changes are, briefly, as follows:

The area above high tide in 1868 was 246.9 acres, while in 1878 it was 227½ acres. During the past 10 years this area has moved in a direction north 28° 30′ west; true course 1,900 feet measured between the centers of position of 1868 and 1878. The movement of the south shore-line on the meridian has been 2,018 feet in 10 years. The greatest movement in any one year occurred in 1873–'74, when it was 670 feet; the least movement, 35 feet, occurred in 1868–'69; the movement from 1877 to 1878 was 300 feet.

The change in shape and position has been greater during the last than any preceding year since 1868, the southeast point of the island having receded 1,200 feet, while the extreme northern point has advanced northward 1,300 feet, *reducing by this distance the width of the north channel entering the Columbia River.* The island is now 8,800 feet long, with an average width of 1,200 feet. Range beacons have been erected on the island to aid mariners in crossing the Columbia River Bar. These beacons are built of drift-logs in the form of a frustum of a pyramid with large targets on top, the whole whitewashed. The range of the outer from the inner of main beacon is south 24° 10′ west, magnetic meridian.

THE UNITED STATES DREDGE AND SCOWS.

At the close of the working season of 1877 the dredge and scows were found to be in very bad condition, the timbers of the former being decayed, the machinery badly worn, and the whole frame racked. The wood-work of the scows was badly decayed, and portions of it would crumble in the hand. By authority of the Chief of Engineers the scows were hauled out and thoroughly repaired during the months of February and March, at a cost of about $2,500. Work was commenced upon the dredge early in May, and by the close of the fiscal year it was placed in good order. The bucket was repaired, new spud, new guide-arm, and new boom supplied, new friction blocks put in, and the whole machinery carefully and thoroughly put in order.

I again call attention to the fact that this pattern of dredge, while excellent for mud, is poor for the character of work upon which it is engaged, and that the bucket becomes badly battered and broken as it falls upon the gravel and hard fine sand, and holds with difficulty the latter.

During the coming season it is proposed to continue work as soon as the freshet will admit, dredging the channel through the various bars between Portland and Saint Helen's, and to scrape the bar at Snag Island. This is necessary in order to keep open navigation, the funds available being insufficient to build either of the dams recommended by the Board of Engineers. In my last report I stated that I thought the first dam to be built should be at the head of the Willamette Slough. The difficulties at Saint Helen's Bar are such that I now think work should be commenced there, for while the dredge can keep open the channel in the Willamette by constant work when the freshet will admit, it cannot keep Saint Helen's open also, and I believe in working first upon the lower bars and then proceeding upward.

The following information, required by the act of Congress approved June 23, 1866, is respectfully submitted.

The appropriations for this work have been as follows:

Act of June 23, 1866, Lower Willamette	$15,000 00
Act of March 2, 1867, Lower Willamette	30,000 00
Act of July 25, 1868, Lower Willamette	21,000 00
Act of April 10, 1869 (allotted)	13,365 00
Act of July 11, 1870, Lower Willamette	31,000 00
Act of June 10, 1872, Lower Willamette	50,000 00
Act of March 3, 1873, Lower Willamette and Columbia	20,000 00
Act of June 23, 1874, Lower Willamette and Columbia	20,000 00
Act of March 3, 1875, Lower Willamette and Columbia	20,000 00
Act of August 14, 1876, Lower Willamette and Columbia	20,000 00
Act of June 18, 1878, Lower Willamette and Columbia	30,000 00
Total	270,365 00

Of this amount $233,553.11 has been expended to date, building dredge, scows, and dike, repairing dredge and scows, dredging and surveying bars.

The present project calls for the construction of dams at Swan Island, at the head of Willamette Slough, at the mouth of the Willamette, and at Saint Helen's Bar; the estimated cost of which is $298,974. Of this amount $150,000 can be profitably expended during the next fiscal year.

While the estimate for the whole work is as given above, it can only be done at those figures if given in large appropriations; with small ones the work will be delayed from year to year, and a large portion of the funds will be expended for dredging that would not be required if the dams were built.

COMMERCIAL STATISTICS.

There are two ports of entry on these rivers: Astoria, 12 miles from the mouth of the Columbia, and Portland, 12 miles from the mouth of the Willamette, or 112 miles from the mouth of the Columbia.

There are two light-houses and two works of defense at the mouth of the Columbia River.

The following information taken from the Portland Commercial Reporter and compiled by Mr. J. R. Farish, of Portland, Oreg., is submitted:

For the year under review, 1877, the statistics point with unerring certainty to very large increase in all departments. Both export and import trade show a marked increase.

The value of the foreign exports for the year 1877 is as follows:

	Cleared from Portland.	Cleared from Astoria.
To Great Britain	$3,850,293	$2,413,987
To Hong-Kong	1,730	
To Sandwich Islands	46,899	13,597
To British Columbia	91,465	1,047
To New Zealand		11,515
To Chili		5,882
To Peru		3,204
To Australia		2,125
Total	3,990,387	2,451,357

The value of the foreign imports for 1877 is as follows:

Entered at Portland	$461,248 00
Entered at Astoria	27,544 00

The value of all exports from the Columbia River for the calendar year 1877, compared with 1876, is as follows:

Articles.	1876.	1877.
Wheat	$3,331,653	$5,785,44
Flour	1,498,434	2,424,50
Salmon, canned and pickled	2,215,000	2,300,00
Meats, canned and pickled	350,000	275,00
Wool	580,000	1,125,00
Lumber, &c	450,000	510,00
Gold and silver	1,300,000	1,191,9
Other products	1,850,000	2,475,00
Total	11,575,087	16,056,

The Commercial Reporter comments on this increase as follows:

> This is a most gratifying increase. Four and a half millions increase in one year by a State that contains a population, based upon the most reliable estimates, of about 140,000 inhabitants is without parallel.

ASTORIA STATISTICS.

I am indebted to Hon. W. D. Hare, collector of customs at Astoria, Oreg., for the following information:

> The amount of revenue collected at the port of Astoria from July 1, 1877, to June 1, 1878, was $16,000. The value of the imports during the same period was $4,234.51, and of the exports $2,141,385.65. Ten foreign vessels, with an aggregate tonnage of 9,251 tons, and 233 coastwise vessels, with an aggregrate tonnage of 273,893 tons, entered, and 56 foreign vessels, with an aggregate tonnage of 63,780 tons, and 229 coastwise vessels, with an aggregate tonnage of 271,686 tons, cleared during the same perod.

PORTLAND STATISTICS.

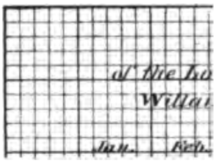
I am indebted to Hon. John Kelly, collector of customs at Portland, Oreg., for the following information:

> The amount of revenue collected at the port of Portland, Oreg., from July 1, 1877, to June 1, 1878, was $131,352.35. The value of the imports during the same period was $460,287, and of the exports, $3,922,228. Forty-six foreign vessels, with an aggregate tonnage of 34,660 tons and aggregate crews of 839 men, and 173 coastwise vessels, with an aggregate tonnage of 191,946 tons and aggregate crews of 6,815 men, entered, and 95 foreign vessels, with an aggregate tonnage of 85,603 tons and aggregate crews of 2,103 men and 115 coastwise vessels, with an aggregate tonnage of 138,970 tons and aggregate crews of 5,561 men, cleared, during the same period.

Abstracts of proposals and contracts, a statement of funds, and a chart showing the channel dredged through Saint Helen's Bar during the year, are transmitted herewith.

Money statement.

July 1, 1877, amount available	$18,584 54	
Amount appropriated by act approved June 18, 1878	30,000 00	
		$48,584 54
July 1, 1878, amount expended during fiscal year		11,772 65
July 1, 1878, amount available		36,811 89
Amount (estimated) required for completion of existing project		268,974 00
Amount that can be profitably expended in fiscal year ending June 30, 1880		150,000 00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Abstract of proposals for furnishing the United States with a tugboat, when required, during the yea 1878, opened by Major John M. Wilson, Corps of Engineers, April 10, 1878.

Number.	Name and residence of bidders.	Furnishing tugboat when required during the year 1878, per month.	Remarks.
1	Wilson Brothers, Portland, Oreg	$525 00	Contract awarded.
2	Baily & Harlow, Portland, Oreg	565 00	
3	W. W. Neilson, Portland, Oreg	572 00	
4	Watson Bros, Astoria, Oreg	700 00	No guarantee accompanying proposal. Bid thrown out.
5	James O. Spencer, Clifton, Oreg	700 00	
6	Megler & Co., Brookfield, Wash	700 00	

Abstract of contract for the improvement of the Lower Willamette and Columbia Rivers, in force during the fiscal year ending June 30, 1878.

Number.	Names and residences of contractors.	Date of contract.	Subject of contract.	Price per month.	Remarks.
1	Bailey & Taylor, Portland, Oreg	February 12, 1877	Hire of steam-tug as tender to United States dredge	$585 00	Contract completed November 11, 1877.
2	Wilson Bros., Portland, Oreg	April 13, 1878	do	525 00	

J J 2.

IMPROVEMENT OF THE UPPER WILLAMETTE RIVER, OREGON.

The portion of this river which has been under improvement during the past four years extends from Eugene City to Portland, a distance of 170 miles.

The various bars and other impediments to navigation, and the methods suggested for their removal, were fully discussed in my last two annual reports, and it is not deemed necessary to repeat them here.

OPERATIONS DURING THE FISCAL YEAR.

Work has been in progress during the year, constructing wing-dams under contract, removing trees, stumps, and snags with the United States snagboat, and making surveys of the various bars where work has been in progress.

WING-DAMS.

The opening of the fiscal year found work in progress under contract with Messrs. Grant & Stone, constructing wing-dams between Corvallis and Oregon City.

The following dams were built during the months of July and August, 1877:

Locality.	Distance from Portland, in miles.	Length of dam built, in feet.	Depth of channel, in feet and inches, before dam was built.	Depth of channel, in feet and inches, two months after dam was built.	Width of channel obtained, in feet.	Remarks.
Black Dog Slough	95½	210	......	......	......	Closing minor channel.
Cut-off above Buena Vista	91	129	......	......	......	Do.
Buena Vista Bar	90½	1,028	2 2	3 6	75	
Long Crossing Bar	88	75	1 0	4 0	100	
Eola Bar	80½	350	2 6	3 6	100	
McCloskey's Chute	63	730½	2 2	6 0	80	
Lone Tree Bar	60	747½	2 6	3 0	75	
Union Bar	50½	162	2 0	3 0	100	
Polalley Bar	17½	408	2 0	4 0	100	
Total length of dams	......	3,840	......	......	......	

In the construction of these dams the following materials were used:

277 piles, driven to an average depth of 8½ feet.
123 bolsters, averaging 30 feet long.
8,267 fascines, 12 inches diameter, 10 feet long.
277 bolts, ¾-inch iron, 20 inches long.
4,160 sand-bags.
61,176 cubic feet of gravel.

After the close of the winter freshet in May, 1878, a careful examination of the dams and bars between Corvallis and Oregon City, a distance of 100 miles, was made in a small boat with the following result:

As a general thing the dams were found to be in good condition, and the channel in every instance improved where they were placed; but, as was to be expected, in several cases symptoms of trouble yet to come were found at points not far below the former ones.

At *Lower Half Moon Bend* the dam built in June, 1877, has accomplished its object. The channel is now nearly straight and presents a depth of about 3 feet at low-water.

At *Bowers Bar* the cut-off dam built in 1876 has been carried away by the freshet. The crib-dam built here in 1872 is an obstruction to navigation and should be removed.

At *Lower Fickel's*, where a dam was built in 1876, there is now no perceptible bar, the depth having been increased from 18 inches to about 5 feet.

At the cut-off *above Buena Vista* the dam has been injured considerably by the freshet, but no material damage has been done, as it had already accomplished its object, and the head of the channel cut-off is filled with gravel, closing it entirely.

At *Eola* the gravel bar in the middle of the channel between the end of the dam and the right bank of the river has been worn away considerably.

At *McCloskey's Chute* the channel has been greatly improved by deepening and straightening. There is a breach of about 30 feet near the lower end, supposed to have been caused by the roots of heavy drift-trees catching in the dam as they passed down.

At *Lone Tree Bar* the dams built in 1876 and 1877 are in good order; but two small gaps were found in the portion built in 1875. The damage is supposed to have been caused by drift-wood.

The bar at this place seems to move down as the dam is lengthened, and I fear we will again have trouble here this summer during low-water.

It is probable that during the present season it will be necessary to repair the gaps at McCloskey's Chute and Lone Tree Bar, and, if so, it can be done by the crew of the snagboat with sand-bags and fascines.

At present the river seems to be available at low-water for light-draught steamboats as far up as Corvallis, though it is possible that during the summer it may be necessary to sluice out the channel with small dams of brush and sand-bags at the lower end of Pine Tree Bar, 2 miles below Albany, at Dove's Bar, 4 miles below Salem, and at the lower end of Lone Tree Bar, 12 miles below Salem. If such is the case, the work can be done by the crew of the snagboat.

THE REMOVAL OF SNAGS.

The opening of the fiscal year found the United States snagboat, in good order and well manned, at work in Hogue's Creek, above Corvallis. The boat was continually engaged upon the river until the 18th of October between Hogue's Creek and Oregon City, and on that day was laid up for the season at Portland on account of high-water.

The season's work was from May 18 to October 18, a period of five months, during which the following work was done:

Locality.	Snags removed.	Estimated weight in tons.
Between Peoria and Corvallis via Hogue's Creek	723	1,817.36
Between Corvallis and Albany	185	463.27
Between Albany and Salem	98	222.15
Between Salem and Oregon City	25	68.80
Total	1,031	2,571.58

In addition to the above, overhanging trees were chopped from the banks from time to time, particularly at the head of Gervais Slough, at which place, on October 10, 50 trees were cut down. The snagboat, therefore, traveled during the season about 250 miles, removed from the channel 1,031 snags, roots, trees, &c., weighing about 2,571 tons, and cut down about 100 overhanging trees.

Of the foregoing, 374 snags were removed previous to July 1, 1877, and the remainder, 657, were removed during the present fiscal year.

There being no available funds, the boat was not put into commission in the spring of 1878. During the month of July, 1877, trouble occurred at McCloskey's Chute, 53 miles below Corvallis, and the suspension of navigation was threatened on account of snags, &c., the snagboat at the time being in Hogue's Creek, above Corvallis. The steamer City of Salem was, therefore, hired for two days to work upon the bar. While so engaged 13 trees, from 80 to 130 feet long, and 3 large stumps were pulled out of the gravel and laid on one side of the channel, where they served to contract the water-way and hasten the formation of a new channel; 9 large trees were cut down from the steep bank and placed where they would least impede the passage of steamers. While the steamboat was tied up pulling snags, the paddle-wheel was kept constantly at work drawing a large volume of water into the new channel and greatly increasing the erosion of the bottom.

A careful examination of the river between Corvallis and Oregon City, made after the subsidence of the winter freshets, showed that the operations of the two previous summers had left the river comparatively clear of snags other than those brought down since the fall of 1877.

It was found, however, that there were 262 snags now in this section which should be removed, and while only a portion of them absolutely demand immediate removal in order to secure an open river this summer, yet unless they are all removed the work next summer will be greatly increased, as the winter's flood will bring down a large quantity of drift which will catch on any obstruction which may then exist in the channel.

It is rather to the persistent and systematic removal of snags than to work done in any one season that the present good condition of the channel is due.

BUOYS.

Five wooden buoys have been permanently attached to the rocks in and near the channel in the vicinity of Rock Island just above Oregon City.

SURVEYS.

Surveys have been made during the year at the various bars where wing-dams have been constructed, and also of the section of the river in the vicinity of Rock Island, and charts prepared showing Bissell's and other rocks. These charts will accompany this report. The following table will show the fall upon some of the rapids between Eugene City and Oregon City:

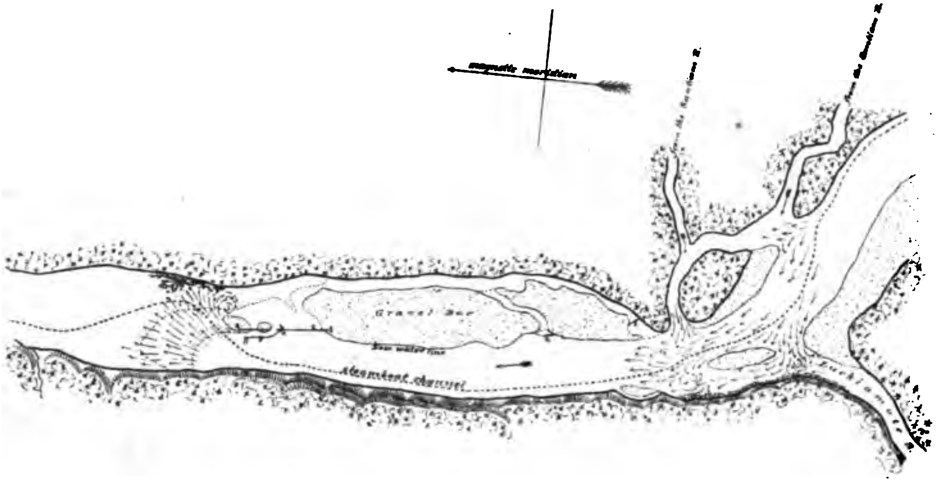
Rapid No. 1	3.82 feet in	500 feet.
Rapid No. 6	2.70 feet in	400 feet.
Rapid No. 8	1.96 feet in	200 feet.
Rapid No. 13	2.15 feet in	350 feet.
Rapid No. 20	2.37 feet in	800 feet.
Rapid No. 24	2.56 feet in	260 feet.
Ohio Chute	3.22 feet in	700 feet.
Scalter Bend	4.82 feet in	650 feet.
Rapid No. 34	2.65 feet in	700 feet.
Rapid No. 37	3.54 feet in	450 feet.
McCloskey's Chute	3.93 feet in	1,100 feet.
Lone Tree Bar	3.33 feet in	350 feet.
Half Moon Bend	2.11 feet in	400 feet.
Luckiamute Bar	1.83 feet in	400 feet.

The last four named are surmounted during extreme low-water by steamboats carrying from 90 to 130 pounds of steam without difficulty; the others are only navigable after a rise of 3 feet above low-water, at which time the fall is reduced about one-third.

At Buena Vista Bar, at low-water, the velocity of the current was found to be about 5 miles an hour, and it is believed that the velocity no where on the river below the head of navigation exceeds 6 miles an hour. During the present season it is proposed, if funds are available, to remove all snags from the channel between Corvallis and Oregon City; to make such repairs to wing-dams as may be necessary; to construct small dams to sluice out the channel where required; to scrape the bars where the worst trouble occurs; and to remove from the channel a portion of the ledge known as Bissell's Rock, and to widen and straighten the channel at Dove's Rock. During the coming fall and winter steam propelling power will be applied to the snagboat.

The present project for this river is as follows:

To build 6,000 linear feet of cut-off dams and 8,000 linear feet of wing-dams, and to construct a snagboat with scraper and pile-driver attached,



BUENA VISTA BAR

Upper Willamette River, Oregon.

Showing the improvements made under the direction of
MAJOR JOHN M. WILSON, U.S. ENG'RS.

July, 1877.

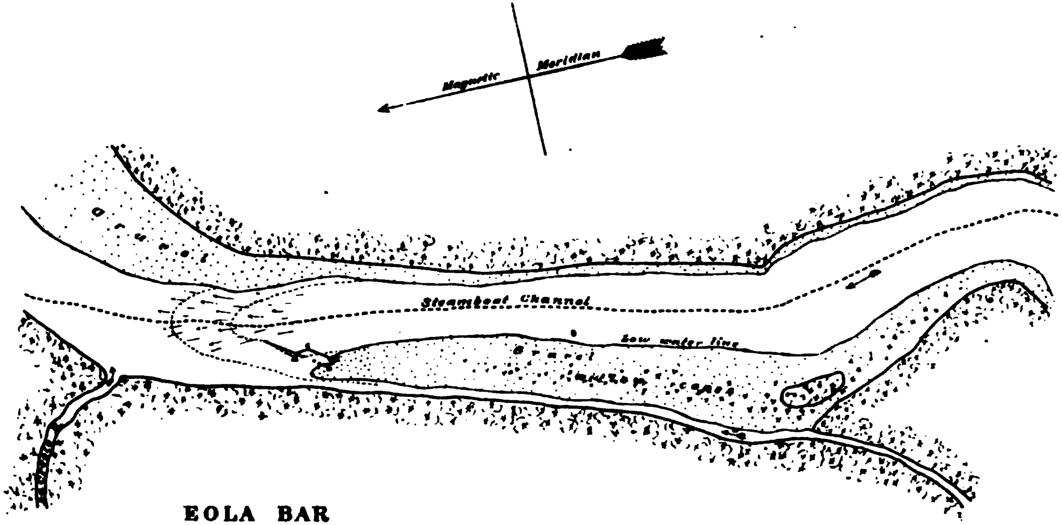
Drawn by Robt. A. Habersham, Asst. Engr.

Scale of Feet.
0 500 1000 2000

h.aa. cf. *built in 1876.*
l.cd. fg. *added in 1877.*
cef. *strengthened and repaired in 1877.*

UPPER WILLAMETTE RIVER
To accompany annual report for June 30th 1878

John M. Wilson
Major of Engineers



EOLA BAR

Upper Willamette River, Oregon.

Showing the improvements made under the direction of
MAJOR JOHN M. WILSON, U.S. ENG'RS.

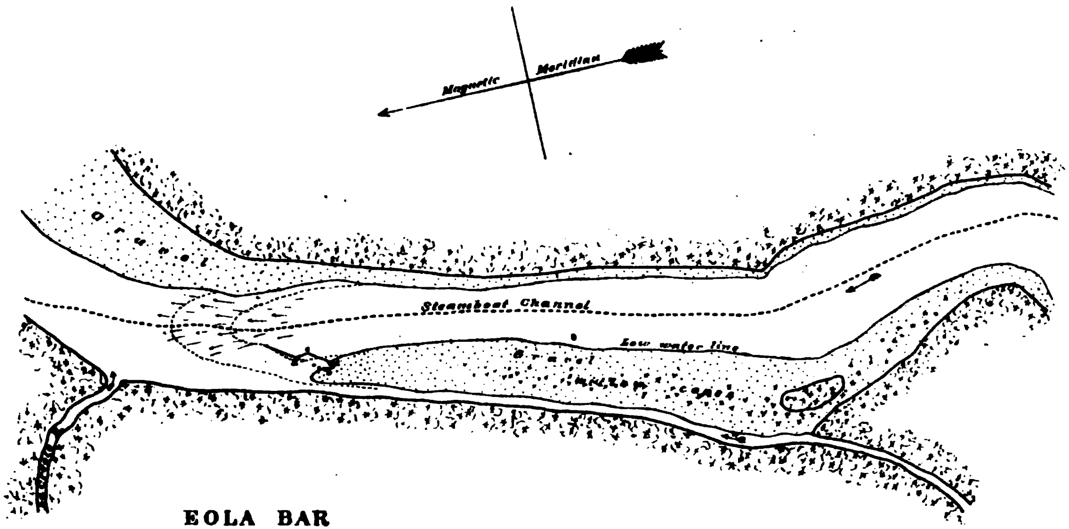
July. 1877.

ab. portion of dam carried away
a.c.d. section built to supply place of ab

Scale of feet.
0 500 1000 1500

UPPER WILLAMETTE RIVER
To accompany annual report for June 30th 1878.
John M. Wilson
Major of Engineers

Drawn by Robt. A. Habersham, Asst. Engr.



EOLA BAR

Upper Willamette River, Oregon.

Showing the improvements made under the direction of

MAJOR JOHN M. WILSON, U.S. ENG'RS.

July, 1877.

ab, portion of dam carried away

a,c,d, section built to supply place of ab

Scale of feet.

0 500 1000 1500

UPPER WILLAMETTE RIVER

To accompany annual report for June 30th 1878.

John M. Wilson

Major of Engineers

Drawn by Robt. A. Habersham, Asst. Engr.

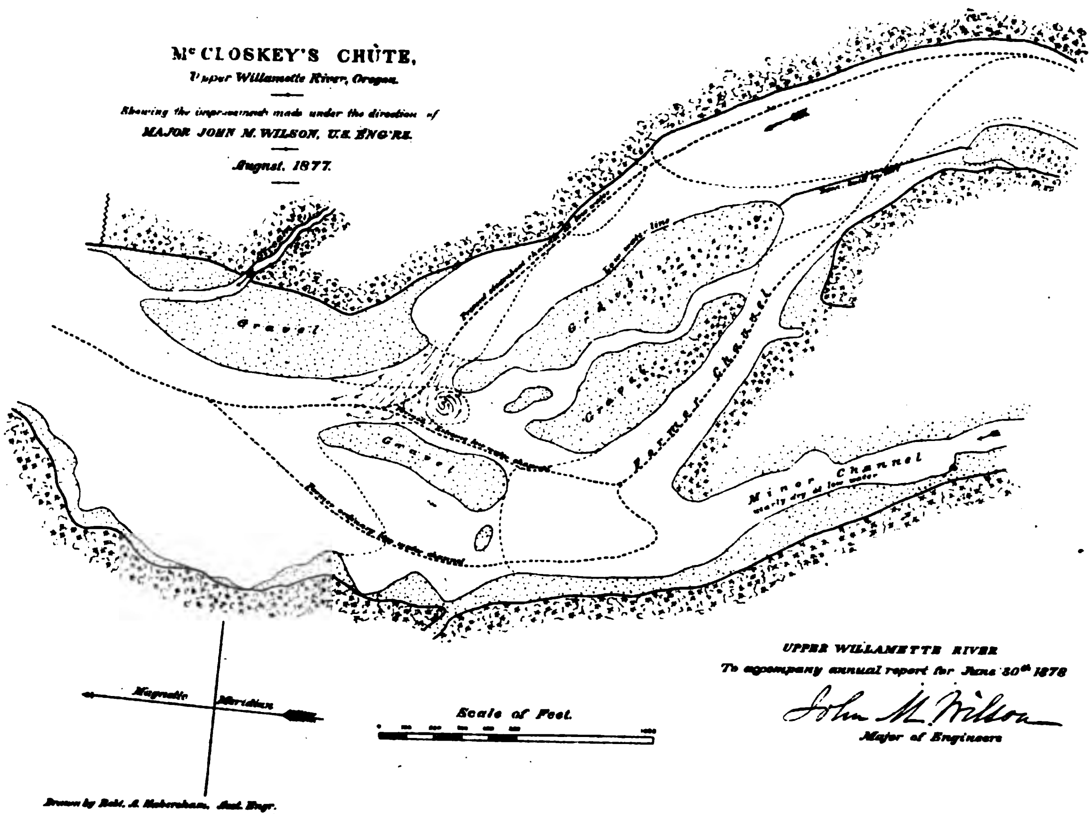
Mc CLOSKEY'S CHÛTE,

Upper Willamette River, Oregon.

Showing the improvements made under the direction of

MAJOR JOHN M. WILSON, U.S. ENG'RS.

August. 1877.



UPPER WILLAMETTE RIVER

To accompany annual report for June 30th 1878

John M. Wilson

Major of Engineers

Drawn by Robt. A. Habersham, Asst. Engr.

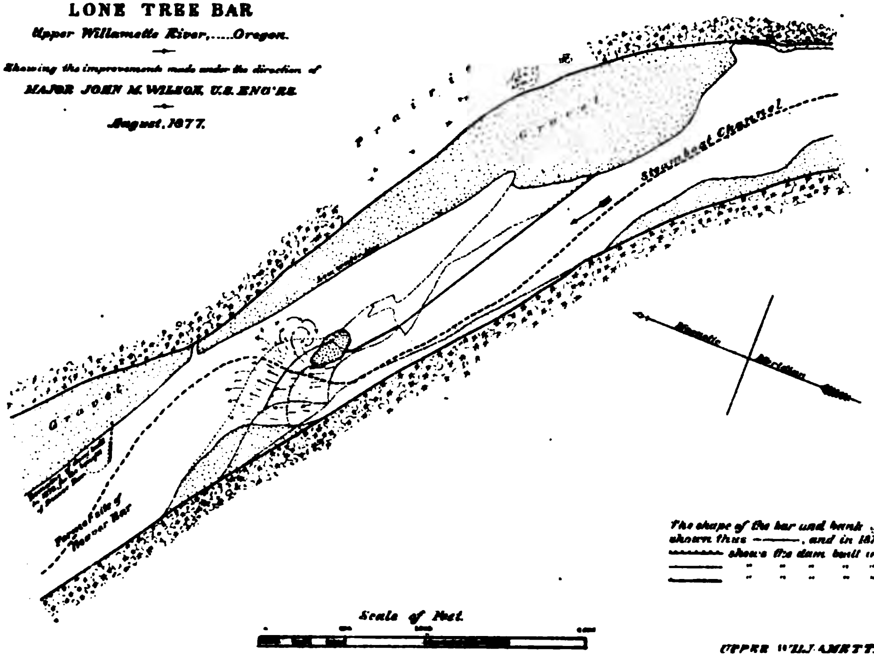
LONE TREE BAR

Upper Willamette River,.....Oregon.

Showing the improvements made under the direction of

MAJOR JOHN M. WILSON, U.S. ENG'RS.

August, 1877.



The shape of the bar and bank of the river in 1875 is shown thus ———, and in 1877 as on maps of other bars.

―――― shows the dam built in 1872.

―――― " " " " " 1875.

―――― " " " " " 1877.

Drawn by Robt. A. Habersham, Asst. Engr.

UPPER WILLAMETTE RIVER

To accompany annual report for June 30th 1878

John M. Wilson

Major of Engineers.

UNION BAR

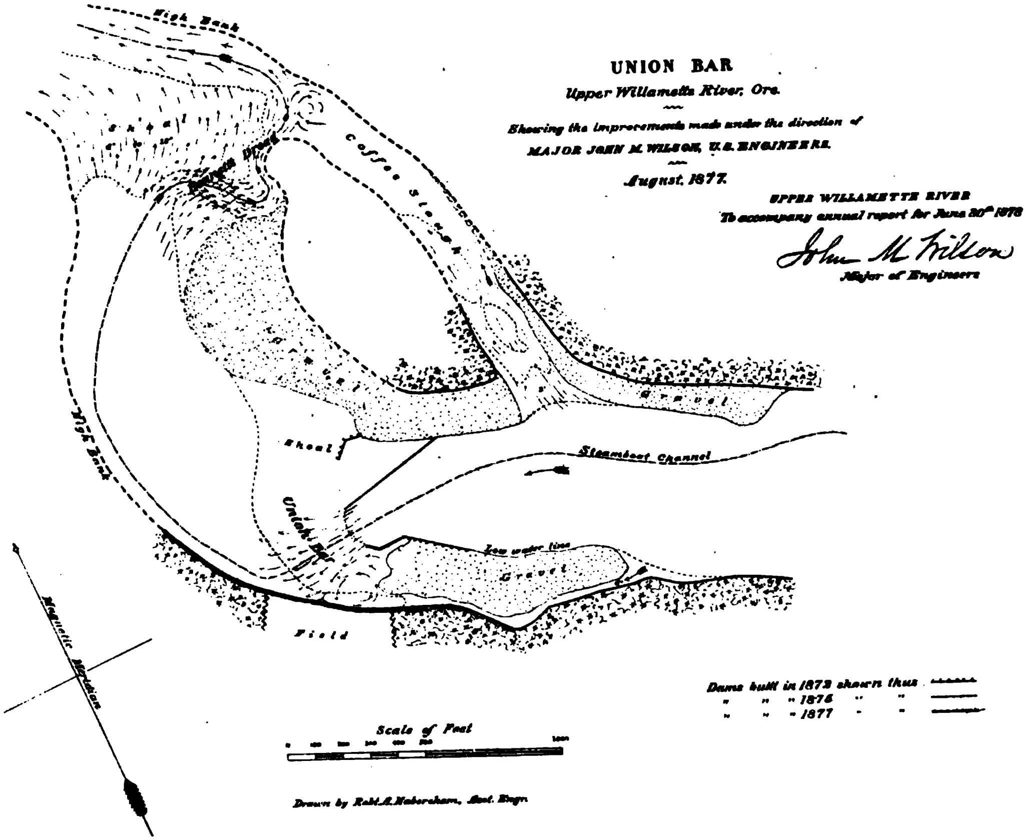
Upper Willamette River, Ore.

Showing the improvements made under the direction of
MAJOR JOHN M. WILSON, U.S. ENGINEERS.

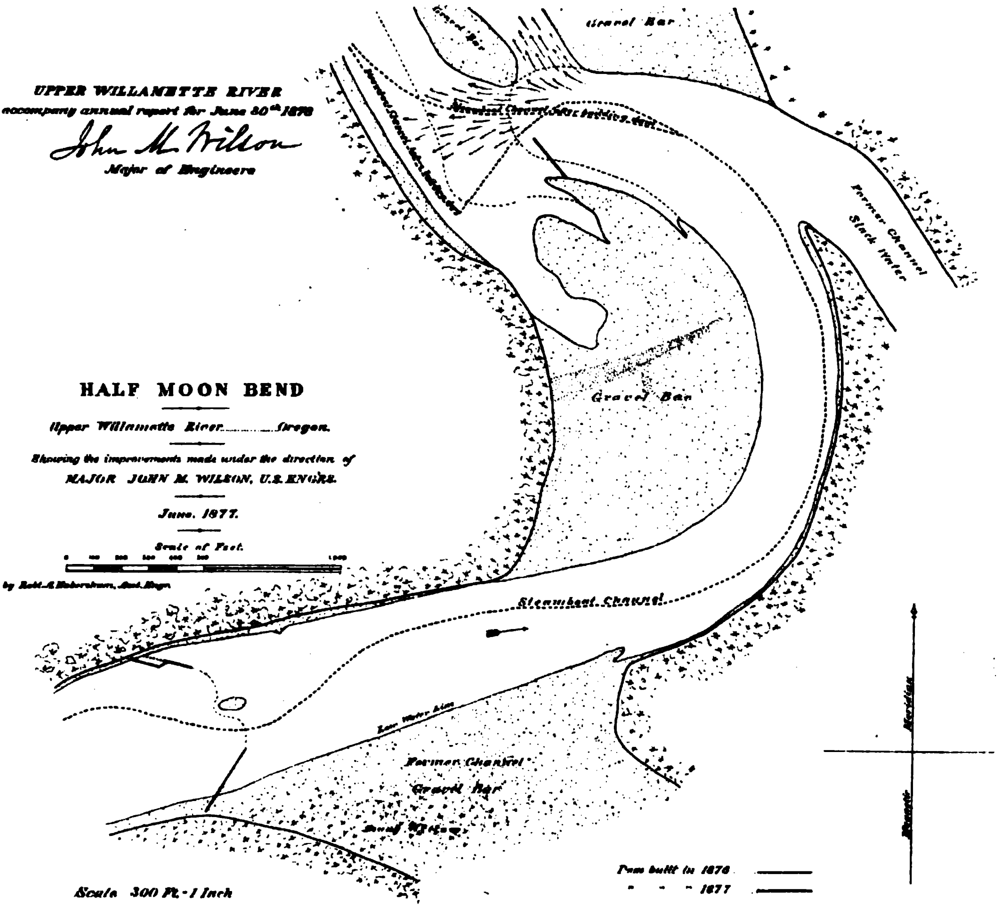
August, 1877.

UPPER WILLAMETTE RIVER
To accompany annual report for June 30th 1878

John M. Wilson
Major of Engineers



Drawn by Robt. A. Habersham, Asst. Engr.



UPPER WILLAMETTE RIVER
To accompany annual report for June 30th 1878
John M. Wilson
Major of Engineers

HALF MOON BEND

Upper Willamette River............Oregon.

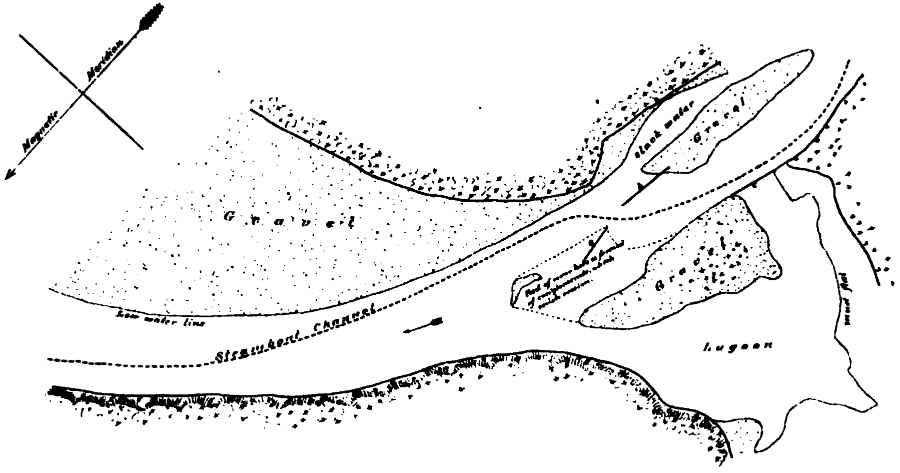
Showing the improvements made under the direction of
MAJOR JOHN M. WILSON, U.S. ENGRS.

June, 1877.

Scale of Feet.

Drawn by Robt. A. Habersham, Asst. Engr.

Scale 300 Ft. = 1 Inch



BOWERS' BAR.

Upper Willamette River, Oregon.

Showing the improvements made under the direction of

MAJOR JOHN M. WILSON, U.S. ENGRS.

June, 1877.

Drawn by Robt. A. Habersham, Asst. Engr.

Scale

0 100 200 300 400 500 1000 ft.

a crib dam, built in 1873
b pile " " " 1877
c " " " " 1876

UPPER WILLAMETTE RIVER

To accompany annual report for June 30th 1878

John M. Wilson

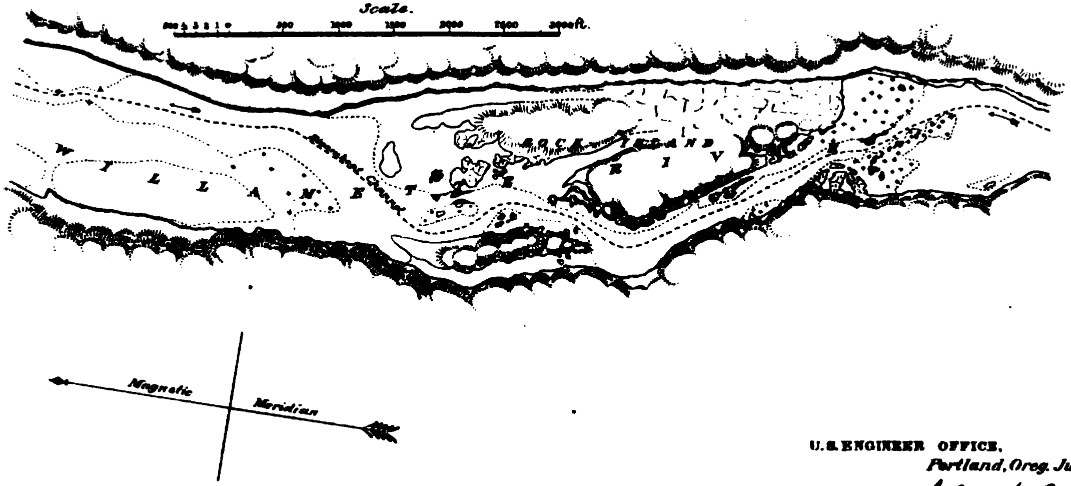
Major of Engineers

Survey of

ROCK ISLAND

Showing rocks to be removed. Made under the direction of Major John M. Wilson, Corps of Engineers. June, 1878.

Scale.



To accompany annual report on Upper Willamette River for June 30th, 1878.

The rocks to be removed are shaded thus: ▲

U. S. ENGINEER OFFICE,
Portland, Oreg. June 30th, 1878.
John M. Wilson
Major of Engineers.

for work above Corvallis; to place steam propelling power on the present snagboat; to remove portions of Bissell's and Dove's rocks above Oregon City; and to make a complete survey between Corvallis and Portland, a distance of 114 miles.

The estimated cost of the project is as follows:

6,000 feet of cut-off dam, at $3	$18,000 00
8,000 feet of wing-dam, at $2	16,000 00
New snagboat above Corvallis	12,000 00
Improving snagboat below Corvallis	6,500 00
Survey between Corvallis and Portland	12,000 00
Maintenance of 2 snagboats, each 6 months, at $900 each per month	10,800 00
Removing 100 yards Bissell's Rock, at $9	900 00
Removing 300 yards Dove's Rock, at $5	1,500 00
Contingencies and engineering	2,300 00
	80,000 00

An annual appropriation of about $12,000 will be required to keep the snagboats in order and run them.

In the operations for the improvement of this river, as well as in many other important works under my charge, I am indebted for valuable assistance to Assistant Engineer R. A. Habersham, who has been active, skillful, and energetic in the discharge of his duties.

The following statistics, required by the act of June 23, 1866, are respectfully submitted.

The appropriations for this work have been as follows:

Act of March 3, 1871	$16,000 00
Act of March 3, 1873	3,000 00
Act of June 23, 1874	7,500 00
Act of March 3, 1875	25,000 00
Act of August 14, 1876	20,000 00
Act of June 18, 1878	20,000 00
Total	91,500 00

Of this amount, $71,373.25 has been expended to date. The project now submitted calls for the construction of certain dams and building and maintenance for one year of snagboats at a cost of $80,000. Of this amount, $40,000 can be profitably expended during the next fiscal year.

This river is in the collection-district of the Willamette; Portland, Oreg., is the nearest port of entry, and the nearest light-houses and works of defense are at the mouth of the Columbia River.

The amount of revenue collected at the port of Portland, Oreg., during the eleven months ending June 1, 1878, was $131,352.35; the value of the imports was $460,287, and of the exports, $3,922,228; 219 vessels, with an aggregate tonnage of 226,606 tons, entered, and 210, with an aggregate tonnage of 224,573 tons, cleared during the same period.

There are three companies now running boats on the Upper Willamette River, as follows: The Willamette Transportation and Lock Company, U. B. Scott & Co., and the owners of the McMinnville and Church.

During the eleven months from July 1, 1877, to June 1, 1878, the Willamette Transportation and Lock Company carried through their locks at Oregon City the following: 6,645 up passengers; 7,399 down passengers; 5,821 tons of up freight, consisting of miscellaneous merchandise; 43,328 tons of down freight; of the latter, 38,996 tons were wheat and flour.

During the same period the boats of U. B. Scott & Co. transported 3,853 passengers and 16,244 tons of freight.

No report of the business of the other company has been received, nor has any notice been taken of the letter from the engineer in charge requesting it.

An abstract of contracts in force during the year, a statement of funds, and nine charts of various bars in the Upper Willamette are transmitted herewith.

Abstract of contracts for the improvement of the Upper Willamette River, Oregon, in for during the fiscal year ending June 30, 1878.

Name and residence of contractor.	Date of contract.	Subject of contract.	5,000 feet wing-dams, more or less, per linear foot.	Remarks.
Grant & Stone, The Dalles, Oregon.	Feb. 26, 1877	Construction of wing-dams.	$1 90	Contract completed Aug 31, 1877.

Money statement.

July 1, 1877, amount available	$14,246 54	
Amount appropriated by act approved June 18, 1878	20,000 00	
		$34,246
July 1, 1878, amount expended during fiscal year		14,120
July 1, 1878, amount available		20,126
Amount (estimated) required for completion of existing project		60,000
Amount that can be profitably expended in fiscal year ending June 30, 1880		40,000

JJ 3.

IMPROVEMENT OF THE UPPER COLUMBIA AND SNAKE RIVERS, OREGO AND WASHINGTON TERRITORY.

As stated in my last annual report, the portions of these rivers to b considered consist of the Columbia from Celilo to the mouth of th Snake, and the Snake from its mouth to Lewiston, a total distance of 2 miles.

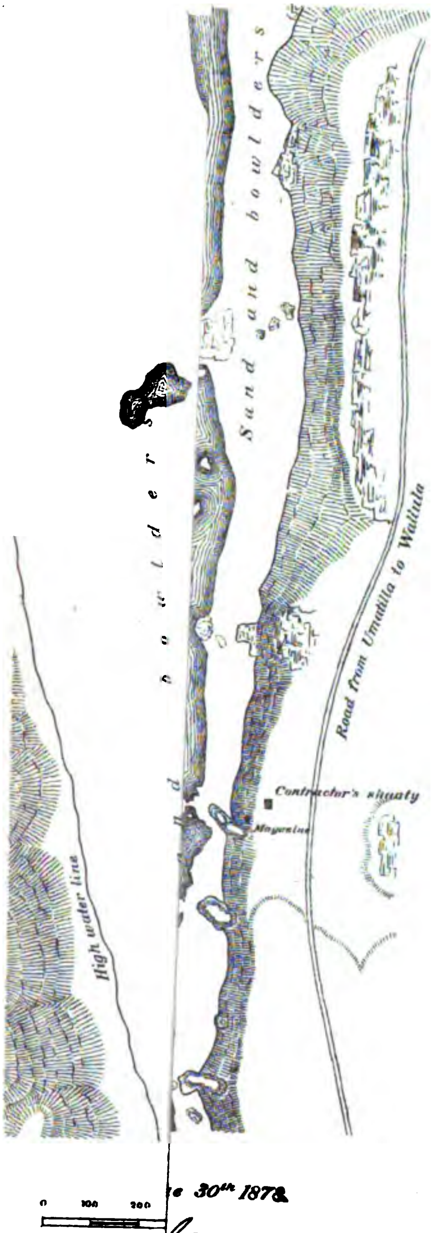
Within this stretch of navigation there are 25 rapids, 16 of which mu be improved before the rivers can be navigated with safety, and 6 o which demand immediate improvement before the Snake River can b navigated at all for more than 4 months of the year. The total amou of rock to be removed in order to reach Lewiston at all stages of th river is about 4,400 cubic yards.

The rapids demanding immediate work are all in the Snake Rive namely, Five Mile, Fish Hook, Pine Tree, Monumental Rocks, Palou and Texas, from which 2,550 cubic yards must be removed, while add tional work is greatly needed at Umatilla Rapids and John Day Rapi in the Columbia.

OPERATIONS DURING THE PRESENT FISCAL YEAR.

UPPER UMATILLA RAPIDS.

The work of improvement here, which consisted of widening the hig water channel under contract with Mr. J. B. Montgomery, and whi was suspended in the latter part of February, 1877, on account of a su den and unexpected rise in the river, was renewed in the month of N vember, 1877, and by the close of December five large and dangero



e 30th 1878

lson

Reduced from the
Engineers.

rocks, and portions of two others equally dangerous, had been removed, as follows:

North side of channel:	Cubic yards.
Rock No. 17	17.35
Rock No. 18	22.33
Rock No. 19	16.88
Part of Rock No. 20	30.61
South side of channel:	
Part of Rock No. 30	5.99
Rock No. 31	28.42
Rock No. 32	25.66
Total	147.24

The removal of these rocks has been of great advantage, and much improved the channel. A great deal yet remains to be done to render this dangerous and difficult rapid safe at all times.

SURVEYS.

A survey has been made of the Upper Umatilla Rapid, and a chart prepared. Reconnaissances have been made of several other rapids.

A buoy has been placed at the upper entrance to the new channel through the Umatilla Rapids.

During the coming fiscal year it is proposed to operate entirely in the Snake River, and to improve the channel at Five Mile and Pine Tree Rapids by removing about 250 cubic yards of rock from the former, and 150 from the latter. The difficulties attending this work are numerous. At the time that it can be done the Snake River is not navigable for steamboats, so that the plant must be hauled to the locality by mules on shore; the current is very swift at the rapids, varying from 5 to 9 miles an hour, and there are no habitations within many miles of the two rapids above named. The best time for work is during the season of lowest water, from September until February, and in December, January, and February operations are often greatly retarded by ice. The small annual appropriations render the work necessarily expensive, as the contractor must have the same plant whether he has 100 or 1,000 yards to remove. The necessity for this great improvement cannot be too fully stated. The country east of the Cascades, which a few years since was thought to be only fit for grazing, has proved to be the very best class of wheat land; settlers are pouring rapidly in, and the valleys of the Walla Walla, the Grande Ronde, the Palouse, and the Spokane, and the country bordering on the Snake will soon be one grand and magnificent wheat garden. Unfortunately, just after harvest, at the very time these people wish to send their crops to market, the Snake River is not navigable, and they are obliged to store their grain until the following spring.

It is earnestly hoped and recommended that this great and very much needed improvement may be pushed vigorously to a rapid completion.

The following information required by the act of Congress approved June 23, 1866, is respectfully submitted.

The appropriations for this work have been as follows:

Act of June 10, 1872	$50,000 00
Act of June 23, 1874	20,000 00
Act of March 3, 1875	35,000 00
Act of August 14, 1876	15,000 00
Act of June 18, 1878	20,000 00
Total	140,000 00

Of this amount, $120,000 has been expended to date, $107,444.71 o the Columbia River at John Day's, Squally Hook, Owyhee, Devil Bend, Umatilla, and Homly Rapids, and $12,555.29 at Pine Tree Rapids on the Snake River.

The present project calls for the removal of 1,500 cubic yards of roc from the Columbia River above Celilo, and 2,900 yards from the Snak between its mouth and Lewiston; the estimated cost of which is $132,00 Of this amount, $75,000 can be profitably expended during the next fisca year.

These rivers are in the collection-district of the Willamette; Portland, Oreg., is th nearest port of entry. The nearest light-houses and forts are at the mouth of th Columbia River, but troops garrison the posts of Walla Walla, about 32 miles fro Wallula, on the Columbia, and Lapwai, 12 miles from Lewiston, on the Snake.

The number of passengers and the amount of freight carried by the Oregon Stea Navigation Company over their portage road at the Cascades is largely in excess of th amount transported during the last fiscal year, and this company has added four larg steamers to their line over this route since the spring of 1877.

I have been informed that the country east of the Cascades, which sends its produc to market via the Snake and Columbia Rivers, raised in 1877 35,000 tons of grain, an the population has increased so much lately by emigration that it is thought that th wheat production in 1878 will be over 50,000 tons.

The amount of revenue collected at Portland, Oreg., during the 11 months endin June 1, 1878, was $131,352.35; the value of the imports was $460,287, and that the exports $3,922,228.

The number of vessels entering was 219, with an aggregate tonnage of 226,606; th number of vessels clearing was 210, with an aggregate tonnage of 224,573.

It is impossible to give an estimate of the amount of commerce tha will be benefited by the completion of this work, as it will increase a the country is developed.

The navigation improved will cover the whole of the Columbia an Snake Rivers from Celilo to Lewiston.

Abstracts of contracts in force during the year, a statement of fund and a chart of the Upper Umatilla Rapids, showing rocks heretofor removed, are transmitted herewith:

Abstract of contracts for the improvement of the Upper Columbia and Snake Rivers in for during the fiscal year ending June 30, 1878.

Name and residence of contractor.	Date of co tract.	Subject of contract.	The Upper Umatilla Rapids, Columbia River, 200 cubic yards, more or less, per cubic yard.	Remarks.
J. B. Montgomery, Portland, Oreg ..	September 2, 1876.	Excavating rock	$31 00	Contract co pleted De 31, 1877.

Money statement.

July 1, 1877, amount available	$5,750 09	
Amount appropriated by act approved June 18, 1878	20,000 00	
		$25,750
July 1, 1878, amount expended during fiscal year		5,750
July 1, 1878, amount available		20,000
Amount (estimated) required for completion of existing project		112,000
Amount that can be profitably expended in fiscal year ending June 30, 1880.		75,000

J J 4.

CONSTRUCTION OF A CANAL AROUND THE CASCADES OF THE COLUMBIA RIVER, OREGON.

On June 7, 1877, the project of the engineer in charge for this canal was referred by the Chief of Engineers to the Board of Engineers for the Pacific Coast for examination and report. The summer freshet in the Columbia being at its maximum when this order was received, the Board delayed action until the river should be low enough to permit a personal examination of the locality.

On August 20, the members of the Board visited the Cascades and on that day and the two following went over the entire ground on both sides of the river. On the 23d they proceeded to Wallula to examine the Upper Columbia, stopping *en route* at the Dalles and Celilo. On their return the Board was again in session, and on August 27, unanimously adopted a resolution approving the location and plans presented by the engineer in charge, with some minor changes as to the size of locks and height of breakwater below them, but directed that before final report should be submitted a survey should be made of the river below the proposed canal as far down as the lower end of Bradford's Island.

Work was immediately commenced on this survey, and it was completed and a large chart prepared by September 17. On September 18, the engineer in charge left for San Francisco, where the Board of Engineers reconvened on the 22d. On the 27th the Board completed their labors and submitted a full report. This report was approved by the Chief of Engineers and submitted by him to the honorable Secretary of War, by whom it was approved on October 12, 1877.

PROPOSED ROUTE OF CANAL.

The route, as approved, is as follows: It commences on the Oregon side of the river just above the main rapid, runs through a pleateau covered with heavy bowlders mingled with sand and gravel resting upon bed-rock, and closely hugging the Oregon shore is continued after the fall is made in the river proper by a crib-work breakwater 4,050 feet long with an average height of 65 feet. The excavation through the plateau will be upon a line 3,150 feet long, including the guard-gate and two locks, and after the fall is made it will continue, where necessary, for 4,050 feet farther within the line of the proposed breakwater.

DIMENSIONS OF PROPOSED CANAL.

The dimensions of the canal will be as follows:

	Feet.
Total length, including crib-work breakwater	7,200
Width in cutting at surface at low-water	50
Width in cutting at bottom at low-water	58
Depth at low-water over miter-sill	8
Depth at extreme high-water over miter-sill	68

The total fall from the upper to the lower boat-landing of the Oregon Steam Navigation Company, a distance of about 5⅔ miles, is 38.4 feet; 26 feet of this is in the first 1⅓ miles, the rest being distributed over a distance of 4⅓ miles. At the upper end of the canal there will be a guard-gate 70 feet wide, the masonry for which, on the west side, will be built to connect with a large mass of conglomerate rock, the east side to connect with a crib-work breakwater running out to the shore. From the south end of the masonry for the west side of this gate another crib-work breakwater will be built parallel to the center line of the canal, to connect with the north end of the west side of the masonry for the lift-locks near the lower end of the plateau, the masonry for the east side of these locks being connected with the shore by another crib-work.

The fall of 26 feet will be overcome by two locks of 12 and 14 feet lifts, respectively, each of which will be 300 feet long by 70 feet wide. These dimensions have been fixed so as to suit the size of boats that will probably run on the river; the difference in lifts is made to more nearly equalize the pressure on the gates. The guard-gates will be 54 feet high, and will have no pressure against them except when the water is drained off from the upper level for repairs. The first lock-gates will be 54 feet high, and will have a maximum strain upon them from a head of 21½ feet when the water in the upper level is 13½ feet above extreme low-water, which will raise the water below the falls 18 feet and bring it to the bottom of the first gate. As the rise below the main fall is 25 per cent. greater than above, the strain on the gate will consequently decrease with any further rise. The middle gates will be 58 feet high and subjected to a maximum strain from a head of 24½ feet water, when there is a rise of 4½ feet above the rapids with a corresponding rise of 6 feet below, bringing the surface of the water below to the bottom of the middle gate. The lowest gate will be 30 feet high, and its greatest strain will be from a head of 14 feet when the river is at its extreme low-water. As long as the river remains higher than 10½ feet above low-water above the falls, which will make it 14 feet below, this gate will be left open. The upper lock walls will be 58 feet high and 29 feet wide at the base, and the lower lock walls 72 feet high and 36 feet wide at the base.

The cutting for the channel across the plateau will be through a soft sand-stone rock, except for a short distance near the upper end, where the surface is covered with bowlders imbedded in sand and gravel to a depth of from 1 to 10 feet; the whole of the bed-rock is water-tight, as proved by water standing in small pools near the site of the locks and from 18 to 24 feet above the level of the river and only a short distance therefrom.

METHOD OF FILLING LOCKS, WORKING GATES, ETC.

The locks will be filled and emptied by culverts in the side-walls, and the lock and sluice gates will be maneuvered by means of water-power, using a turbine wheel with the necessary shafts and miter-wheels. Attention is respectfully invited to the report of Assistant Engineer C. M. Bolton, transmitted herewith, in which the method of working gates, &c., is fully described. This exceedingly simple and ingenious plan is entirely original with Mr. Bolton, who has made a very careful study of it, and for which he deserves great credit. This machinery has been applied to a model of the locks which has been constructed, and works admirably.

LAND REQUIRED FOR THE CANAL.

On October 17, 1877, the Chief of Engineers notified the engineer in charge of the approval of the report of the Board of Engineers, and directed him to report the amount of land required, price asked, names of owners, &c., in order that the facts might be placed before the Secretary of War for his action before purchase. This letter was received on

October 30, and on October 31 a full report was forwarded. The land required, 47.32 acres, was claimed to be owned by the Oregon Steam Navigation Company, who offered to sell it at the rate of $200 per acre, reserving to themselves the right of way across for a railroad. The honorable Secretary of War declined to purchase with the reservation asked by the company, and on December 31 the engineer in charge received orders from the Chief of Engineers, under date of December 17, to commence proceedings for the condemnation of the land under the laws of Oregon. On the day of the receipt of this order (December 31) all the papers in the case were placed in the hands of the United States district attorney, who was requested to at once take action for the condemnation of the land. On the same day the district attorney informed the engineer in charge that under the laws of Oregon, section 24, page 350, general laws, edition of 1874, no more than 60 feet in width could be condemned, and as this would not give the United States sufficient land for their purposes, the facts were at once reported to the department.

On the 31st of December, the engineer in charge notified the Oregon Steam Navigation Company that orders had been received to proceed to condemn the land, and stated that he would gladly forward any further communication they desired to make to the Chief of Engineers. On January 1, the vice-president of the company requested that action for condemnation might be suspended for a few days, as he believed arrangements could be made whereby his company would waive their request to reserve the right of way for a railroad. After consultation with the vice-president of the company, the engineer in charge agreed to leave out 4.45 acres which were desired in order to use as roads for access to the county road, and to get a house for the use of the engineer party while work was in progress, and the company agreed to waive their request for a right of way, to give the United States the right of way across their land to the county road, and the use of the house desired as long as the work of construction was in progress. In the mean time another question had arisen to give trouble: In the autumn of 1875 the Columbia River Improvement Company had had condemned for their use, for canal purposes, a strip of land, 60 feet wide, containing 5 acres; the Oregon Steam Navigation Company claimed that their title was not good, but as yet it had not been carefully examined for the United States by the district attorney; for this 5 acres, under date of December 31, 1877, this company, through their attorney, asked the enormous sum of $10,000; afterward, under date of February 20, the company reduced their offer to $2,000, but too late for action, as orders had already been received to proceed as soon as practicable to condemn the land. On January 7, 1878, the engineer in charge reported to the Chief of Engineers the last offer of the Oregon Steam Navigation Company and the offer of the Columbia River Improvement Company, dated December 31. On January 12, learning that a law had been passed by the Oregon legislature on October 20, 1876, authorizing the United States to take proceedings for condemnation of all land required for canal purposes, provided such property could not be purchased, the engineer in charge immediately notified the Chief of Engineers of this law. All the facts having been placed before the honorable Secretary of War, telegraphic orders were received on the evening of February 18 directing proceedings for condemnation to be commenced under the laws of Oregon as soon as practicable. On the morning of February 19 all the papers in the case were placed before the United States district attorney, and on February 23 the engineer in charge made the necessary affidavit as to the land required before the clerk of the

United States district court. The case came up before the United States district court for Oregon, and early in April the Oregon Steam Navigation Company was granted until June 1 for reply. Their reply was made on that day, and information has since been received from the United States district attorney and the clerk of the court that it will be impossible to get a jury to try the case before some time in July.

The engineer in charge has gone fully into details in this report in reference to the land, as he desires all the facts to go on record. In his intercourse with the officers of the Oregon Steam Navigation Company before proceedings for condemnation were commenced he received every courtesy, and although he considered the price asked, $200 per acre, high, they were perfectly ready to sell at that price, and offered the 42.87 acres required, with perpetual right of way across their land to the county road, and the use of their house as long as work was in progress, for $8,574.

SURVEYS.

A survey has been made during the year of the river from the lower end of the proposed canal to the lower landing, a distance of 3½ miles, and a chart prepared. The lines of the land required for the canal were run so as to fully describe it by metes and bounds in the deed, and also to locate the limits of the land claimed by the Columbia River Improvement Company. A chart has been prepared showing the limits of this land, with the names of the various claimants.

MODEL OF LOCKS AND CRIB-WORK.

By authority of the Chief of Engineers, a complete model, on a scale of 1 inch to 4 feet, has been constructed. This model shows every detail of the crib-work and masonry, including locks, culverts, &c., and all the machinery for working the gates and valves and filling and emptying the locks. The machinery of this model is worked by a small turbine wheel, to which water-power is applied through a hose. The model will be of great assistance to contractors in bidding upon the work.

WIDTH OF LOCKS.

The Board of Engineers recommended that the locks should be 50 feet wide, but in May, 1878, the engineer in charge called the attention of the Chief of Engineers to the fact that the rapid development of the country east of the Cascades would probably demand at an early day much larger boats than those now in use, in order to bring the immense grain crops to market, and suggested that, as the increase of expense would be only about $30,000, it would be better to build the locks at once 70 feet wide than to be called upon at great expense and inconvenience in the future to widen them. This suggestion was approved by the honorable Secretary of War and the Chief of Engineers, and the width of 70 feet was adopted.

During the coming fiscal year it is proposed, in case we are able to get possession of the land in time, to excavate for foundation of the locks, and to build them both up to within 3 feet of the level of the upper pool. If we are able to do this, hereafter, if funds are available, we can push the work with sufficient rapidity to keep above the level of freshets. If, however, we are delayed until October before the final decision of the Attorney-General can be obtained upon the title, then we will be able to do only a small amount of work before we are driven off by the spring rise from the Snake River in February.

In the survey, preparation of plans, estimates, and models, I am greatly indebted for valuable assistance to Assistant Engineer C. M. Bolton. His very ingenious device for working the gates, valves, &c., has been commended by all who have seen it. In the discharge of his official duties he has been active, energetic, and skillful. Like myself, he anxiously awaits the slow process of law, whereby we must get the land in order that we may rapidly push forward this great and much-to-be-desired improvement.

The following statistics, required by the act of June 23, 1866, are respectfully submitted.

The appropriations for this work have been as follows:

Act of August 14, 1876	$90,000 00
Act of June 18, 1878	150,000 00
Total	240,000 00

Of this amount, $10,470.70 has been expended to date in surveys, preparation of plans and model, expenses of the Board of Engineers, salaries of assistant engineer and draughtsman, and office expenses.

The revised estimated cost of the project, as approved by the Board of Engineers for the Pacific coast, is $1,753,867; of this amount, $500,000 can be profitably expended during the next fiscal year.

The Cascades of the Columbia River are situated in the collection-district of the Willamette. The nearest port of entry is at Portland, Oreg., 65 miles distant; the nearest light-houses and works of defense are at the mouth of the Columbia, about 160 miles distant. I am informed that the number of passengers and the amount of freight passed over the portage railroad at the Cascades by the Oregon Steam Navigation Company during the present fiscal year are largely in excess of the number and amount transported during the same period in the last fiscal year.

The amount of revenue collected at the port of Portland, Oreg., from July 1, 1877, to June 1, 1878, was $131,352.35; the value of the imports was $460,287, and of the exports $3,922,228; 219 vessels with an aggregate tonnage of 226,606 tons entered, and 210 with an aggregate tonnage of 224,573 tons cleared.

At the port of Astoria during the same period as above the revenue collected was $16,000; the value of the imports was $4,234.51, and of the exports $2,141,385.65; the number of vessels entering was 243 with an aggregate tonnage of 283,144 tons, and the number clearing was 285 with an aggregate tonnage of 335,466 tons.

By the construction of the Cascades Canal direct navigation of the Columbia will be opened to the Dalles, a distance of 50 miles beyond the Cascades. The amount of commerce to be benefited cannot be given in figures, but its great increase is anticipated from the fact that large numbers of emigrants are rapidly settling east of the Cascades and developing that magnificent wheat-growing region.

I respectfully request that the chart showing the location of the canal, forwarded with my last annual report, the one showing the river immediately below, forwarded with my letter of October 27, 1877, and the plan of the locks, forwarded herewith, may be published with this report.

The report of Assistant Engineer C. M. Bolton, a statement of funds, and a drawing showing a plan and sections of the proposed locks are transmitted herewith.

Money statement.

July 1, 1877, amount available	$85,383 35	
Amount appropriated by act approved June 18, 1878	150,000 00	
		$235,383 35
July 1, 1878, amount expended during fiscal year		5,854 05
July 1, 1878, amount available		229,529 30
Amount (estimated) required for completion of existing project		1,524,338 00
Amount that can be profitably expended in fiscal year ending June 30, 1880		500,000 00

REPORT OF MR. CHANNING M. BOLTON, ASSISTANT ENGINEER.

UNITED STATES ENGINEER OFFICE,
Portland, Oreg., June 29, 1878.

COLONEL: In my last annual report I gave a full description of the location of the Cascade Canal, with reasons for the selection of the adopted line. In accordance with instructions from you, I have been engaged during the intervening time in extending surveys down the river to the Oregon Steam Navigation Company's lower landing, about 3 miles on the Oregon and 6 on the Washington Territory side, including careful soundings and observations on the velocities of the currents of the river, which are all shown on chart submitted September last.

I have also been perfecting plans and specifications for construction, and building a complete working model on a scale of one-forty-eighth, which is now finished.

During the past season we have had no very high water, the river rising only to within 14 feet of its maximum height. I have been unable as yet to see it at its highest stage, but, from observations taken, I have no reason to change my opinion as to its being navigable to the lower end of the breakwater as now located.

During the past few months the Oregon Steam Navigation Company has been constructing a portage railroad, the location of which lies across the site of the breakwater connecting the guard-gate with the high ground. This railroad will have a grade-line below high-water, so that unless some arrangement be made with that company the location of the breakwater will have to be changed.

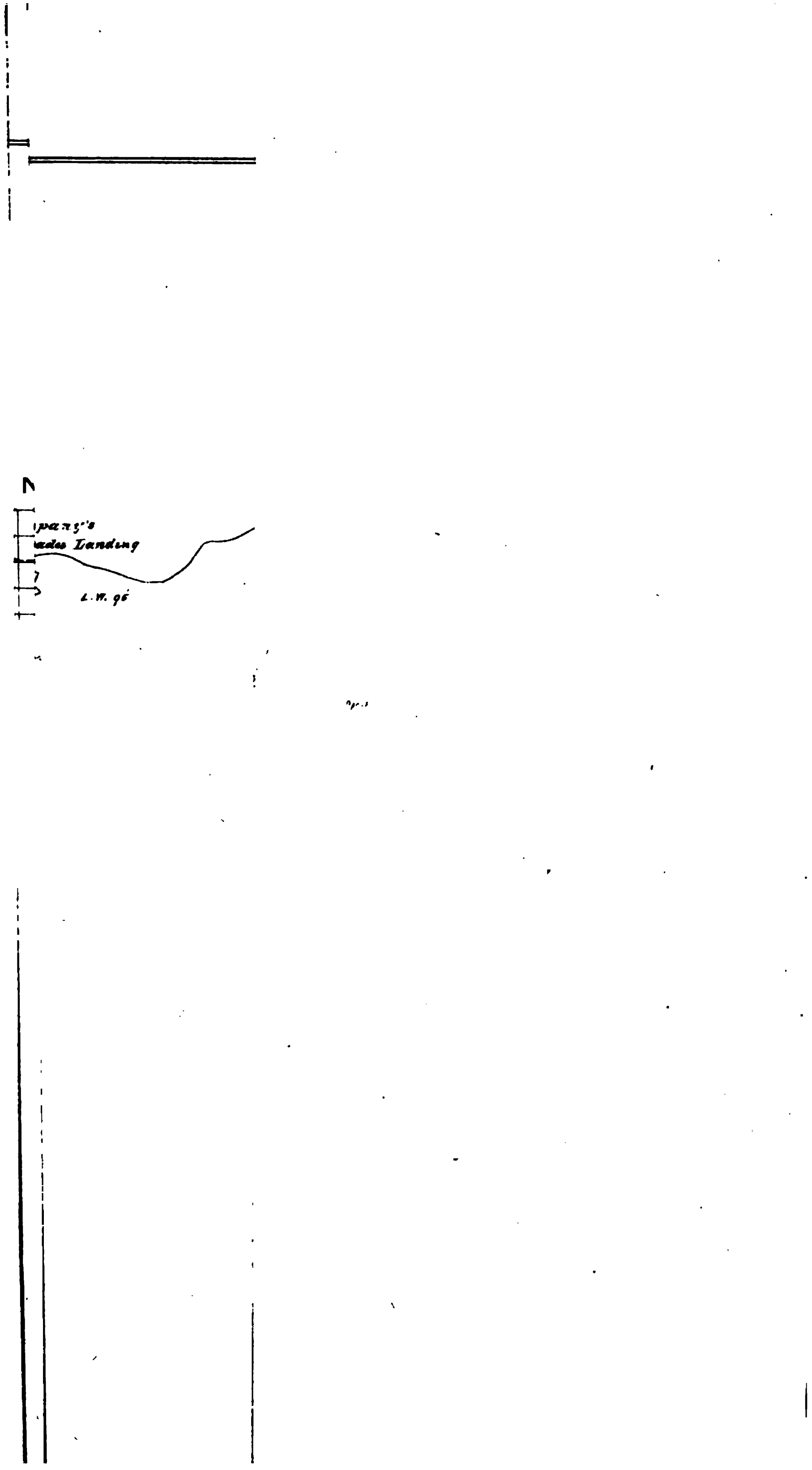
The only other alteration of the adopted plan that I can suggest at present is that the docks be made 70 feet wide, instead of 50 as proposed. The 50 feet is ample width for any boat likely to be built of the style (stern-wheel) now used on the river, the largest of which at present in use is 39 feet wide and 240 long. But I think side-wheel boats can be used to advantage and will be built when the proposed width would be too narrow. A boat requiring the other dimensions of the canal, 300 feet long with 8 feet over the miter-sill, can be run to much better advantage with side wheels. The additional width I would advise to be made only in the guard-gate and locks, the canal being left as now proposed, to be widened when required, as this could be done at that time without any additional cost in consequence of the delay. This change would increase the cost by a very small percentage, the principal cost, that of the masonry, remaining the same, except in the little addition to the miter-sills and lift-walls. This would secure full capacity for all time, whereas if it should become necessary to widen in the future, it could be done only by an expenditure probably equaling one-half the present estimated cost and with serious interruption to business.

PLAN OF PROPOSED CONSTRUCTION.

As the guard-gate will be seldom used, the movements will be made by hand power and the water discharged through sluices in the gates.

In the locks the sluices to be built in the side walls. Two 3 feet by 4 feet rectangular culverts enter the side walls at the bottom of the lock-chambers just above the gate recesses; these, with curves of such radii that do not materially interfere with the flow, connect with culverts running parallel to the axis of the canal, near the rear of the walls; these culverts to have vertical side walls 4 feet high spanned by semicircular arches of 5 feet diameter; the water is then discharged from each of these culverts through four cast-iron pipes of 3 feet diameter each, whose outflow ends are below the surface of the water in the lock-chamber. This will raise or lower the boats with great evenness, as the flow of the water for changing the level will be distributed over the entire length of the boat. This plan will be used to fill the first lock from the head-bay, the second lock from the first, and to lower the water in the second lock, except that in the last case the arched culverts will continue around the lower gates and discharge themselves into the tail-bay, instead of through pipes.

The gates and valves of the locks will be moved by a system of shafting run by a turbine-wheel, viz: A main shaft will be placed near the top of the masonry of the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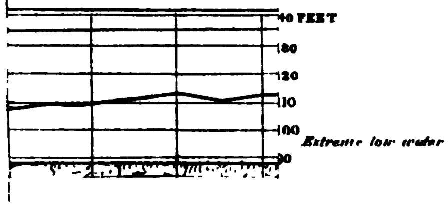

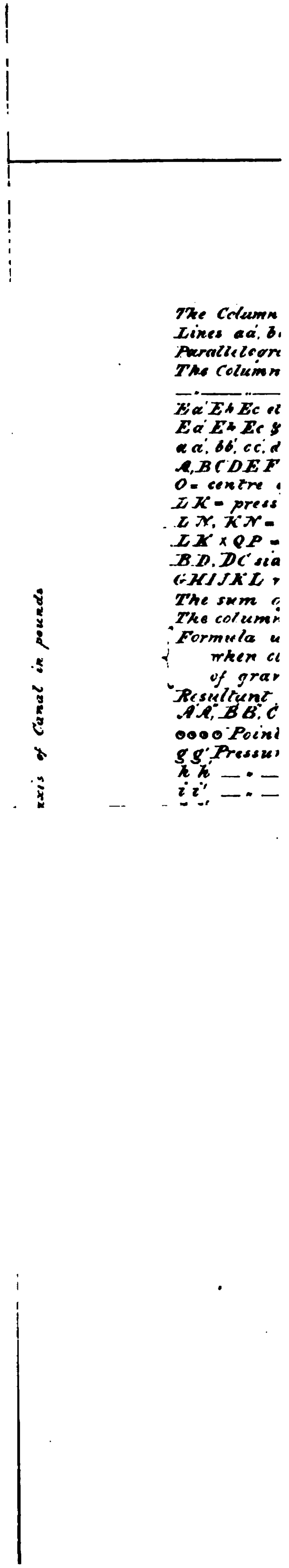
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eastern wall, extending nearly the length of the two locks and parallel to the axis of the canal. Motion is imparted to this shaft by a turbine-wheel placed opposite its center and connected with it by a shaft placed at right angles thereto; this shaft being geared to the main shaft by either of two miter-wheels by means of a clutch which gives forward or reverse motion as desired. Power is thus taken from the main shaft at the several points where it is needed by friction-clutches. To move the sluice-gates, which are placed just at the mouths of the sluice-culverts, shafts are set vertically in well-holes left in the wall directly under the main shaft and between the sluice-culverts. These vertical shafts are geared at their tops into the main shaft by miter-wheels and at their lower ends into horizontal shafts extending across the bottom of the canal. These last shafts have worms cut on them just between each set of valves, the worms working into wheels made fast to the center of shafts, on the ends of which are right and left hand screws working into nuts fastened to the valve-gates, so that a motion in one direction draws the valves toward each other, thereby opening the sluice-culverts, while motion in the opposite direction draws them apart, closing them and shutting off the flow of water.

The gates are also moved by the same main shaft geared into shafts, on the ends of which are drums to which are attached wire ropes connecting them with the gates, so that motion in one direction opens the gates and the reverse closes them. This will be worked by two attendants, one remaining at the first clutch near the turbine, while the other walks along the line of main shaft, throwing the clutches in or out of gear at the several points where power is needed, and by signal to the first man getting either forward or reverse motion as he desires. There are also valve-gates, to be worked by hand, placed across the arched culverts, which can be used and shut off the water in case of accident to the machinery. The ropes are also so arranged that they can be detached, allowing the gates to be worked by hand. The model and plans in the office show clearly these arrangements.

In starting the construction, I would advise the foundations for the locks be excavated as soon as possible, so that the masonry can be begun during low-water; this would place the work in such condition that it could be continued without interruption during the entire year should the necessary appropriations be made. The river is now near its maximum height for the year and will soon begin receding.

A diagram is herewith submitted showing the resultant pressures against the lock-gates from a head of 25 feet of water, giving the directions and amounts of pressures for each foot of depth. It shows the strains against the gate-timbers and thrusts against the abuttresses. The explanations accompanying fully explain it.

Very respectfully,

CHANNING M. BOLTON,
Assistant Engineer.

Col. JOHN M. WILSON,
Major Corps of Engineers.

LETTER TRANSMITTING REPORT OF BOARD OF ENGINEERS FOR THE PACIFIC COAST.

BOARD OF ENGINEERS FOR THE PACIFIC COAST,
San Francisco, Cal., September 27, 1877.

GENERAL: I have the honor to inclose herewith to the department a report of the Board of Engineers for the Pacific Coast on the project of a canal around the Cascades of the Columbia River called for by letter of the department of June 7, 1877. The report is dated September 24, 1877.

* * * * * * *

Very respectfully, your obedient servant,

B. S. ALEXANDER,
Lieutenant-Colonel of Engineers,
Pres't Board of Engineers Pacific Coast.

Brig-Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

[First indorsement.]

OFFICE OF CHIEF OF ENGINEERS,
October 10, 1877.

Respectfully submitted to the honorable the Secretary of War.

The views and recommendations of the Board of Engineers for the

Pacific Coast on the project for a canal around the Cascades of the Columbia River, Oregon, for which an appropriation of $90,000 was made by the river and harbor act of August 14, 1876, appear to be judicious and are concurred in by me. I have, therefore, to recommend that they be approved.

A. A. HUMPHREYS,
Brig. Gen. and Chief of Engineers.

[Second indorsement.]

Approved.

GEO. W. MCCRARY,
Secretary of War.

OCTOBER 12, 1877.

REPORT OF BOARD OF ENGINEERS FOR THE PACIFIC COAST.

OFFICE BOARD OF ENGINEERS FOR THE PACIFIC COAST,
San Francisco, Cal., September 24, 1877.

GENERAL: In compliance with the instructions of the department of June 7, 1877, the Board of Engineers for the Pacific Coast has now the honor to submit a report on the project, dated April 12, 1877, for a canal around the Cascades of the Columbia River, submitted to the Engineer Department by Maj. John M. Wilson, Corps of Engineers, April 13, 1877.

The water in the Columbia River having fallen sufficiently to permit an inspection of the ground upon which the proposed canal is to be located, the Board proceeded to that river in August last, and devoted two days to an examination of all possible routes for a canal around the Cascades on both sides of the river.

The result of this personal examination was to convince the members of the Board that the left bank, or Oregon side of the river, presents the best location for a canal around the Cascades. The surveys had already pointed to this conclusion; but surveys, however minutely made, are rarely as convincing in such matters as an inspection of the locality itself.

There is no suitable ground for the location of the canal-locks, or for the canal itself, along the river-bank on the Washington Territory side of the river; and if we go back from the river and seek a location for the canal, we encounter a ridge some 200 feet high, and of such width as to render the cost of cutting a canal through it so great as to preclude the possibility of such a route.

On the Oregon side of the river, however, there is a rocky plateau, which affords a good location for the canal-locks, with a safe and convenient approach to the canal from above; while below the locks the canal may be kept close to the shore, and protected from the river current and drift by a breakwater or guard-wall.

This mode of constructing the canal below the locks is rendered necessary because there is no possibility of hillside cutting for a channel, in consequence of the steep slope of the adjacent shore. Any excavation for a canal at the foot of this slope would start large masses of material extending high up on the slope of the mountains.

Sliding is clearly apparent even now at a point between the lower end of the canal, as planned by Major Wilson, and the upper end of Bradford's Island.

This sliding appears to take place on a stratum of sandstone beneath the overlying material, upon which perhaps a protection wall to guard the canal from being filled up by future slides may be founded.

In view of these facts the Board approves the location and plan of the canal as prepared by Maj. John M. Wilson, of the Corps of Engineers, but the Board is of opinion that the dimensions of the locks should be increased to 300 feet in length instead of 250, and to 50 feet in width instead of 46 feet.

The Board further thinks that in order to make the canal more secure, render it navigable at all times, and guard against drift in high-water, the height of the breakwater below the locks should be sufficient to exclude the flood-waters of the river from the canal or water-way behind it.

If the canal as projected by Major Wilson were built, it is the opinion of most of the steamboat men with whom we had an opportunity of conversing that it would be navigable; that is to say, that the steamboats now navigating the river could pass up the lower cascade rapids into the canal, and thence through the canal and its locks to quiet navigation above the main fall of the Cascades.

On account, however, of the great velocity of the water in the river at and for nearly 3 miles below the lower end of the canal as planned by Major Wilson, the navigation through these lower rapids will necessarily be somewhat dangerous and it must always be very expensive.

As the commerce of the river increases and boats of heavier draught come to be used, these difficulties may so increase as to render necessary an extension of the breakwater down the river so as to join on to the upper end of Bradford's Island, a distance of about 1½ miles.

In that case the channel on the inside of this island should be excavated where necessary to the proper depth, so as to form the canal, the lower entrance to which will then be behind the island, and below all the principal rapids in this portion of the river. This change when made will involve the construction of an additional lock with a lift of 10 or 12 feet at or below the falls in rear of Bradford's Island.

The cost of this extension of the canal with an additional lock, as near as we can now estimate it, according to present prices will be in round numbers, $1,000,000, making the total cost of the entire canal around the Cascades of the Columbia River according to present estimates $2,544,545.

Here, perhaps, this report might close, but it appears to the members of the Board that it might be regarded as incomplete without some statement of the magnitude and importance of the Columbia River and the relations of the proposed canal around the Cascades to its navigation considered as a whole.

The Columbia is the great river of the Pacific coast. It rises in the British possessions, flows in a southerly direction through Washington Territory as far as Wallula, and thence westerly to the Pacific Ocean, having its mouth in latitude about 46° 14′ north, longitude 124° west.

Its principal tributaries are the Snake and the Willamette Rivers. The Snake River rises in the Rocky Mountains of Wyoming Territory, flowing first westerly, then northerly, and again westerly, having its confluence with the Columbia 11 miles above Wallula and about 340 miles above the mouth of that river.

The Willamette River rises in the Cascade Range of mountains in Oregon. It flows northerly, having a course of about 200 miles from its source to its mouth in the Columbia, about 12 miles north or below the city of Portland.

The Columbia River is navigable for sea-going vessels as far as the mouth of the Willamette, a distance of about 100 miles from its bar, and the Willamette is navigable for sea-going vessels as far as Portland, which is at present the principal commercial city in the State of Oregon.

The navigation of the Lower Willamette and the Columbia Rivers from Portland to the sea is therefore free to the commerce of the world.

From the mouth of the Willamette to the Lower Cascades of the Columbia River, a distance of about 53 miles, there is a depth of at least 10 feet of water at the lowest stage of the river. At this point the navigation of the Columbia River is interrupted by the Cascades for a distance of about 6 miles. It is to overcome this impediment to navigation that the present project for a canal around the Cascades has been proposed.

Above the Cascades to The Dalles, a distance of about 45 miles, there is a depth of water in the Columbia of 8 feet at the lowest stage of water in the river.

Between The Dalles and Celilo, a distance of about 15 miles, the navigation of the river is interrupted by a succession of falls and rapids.

From Celilo to the mouth of the Snake River, a distance of about 117 miles, the river is navigable at all stages by light-draught steamers, except when it is closed by ice; but the channel, at low-water, is tortuous, the rapids numerous, difficult of ascent, and rendered dangerous by hidden rocks.

Improvements on this portion of the river, in the way of removing these hidden rocks, have been in progress for the last few years, by which the navigation has been greatly benefited.

From the mouth of the Snake River to Priest's Rapids, a distance of about 75 miles, the Columbia River is also navigable for light-draught steamers. Here the navigation in the river is again interrupted by a direct fall of a few feet, the exact height of which is not known.

Above Priest's Rapids the Columbia again becomes navigable for light-draught steamers. A few years ago a steamboat was running on this portion of the river, but at present there are no steamers on this upper reach of the Columbia.

On account of many difficult and dangerous rapids, the Snake River at present is not navigable during low-water, or for about eight months of the year. From about April 1 to August 1, it is navigable for light-draught steamers as far up as Lewiston, a distance of about 145 miles above its mouth. Beyond Lewiston navigation is interrupted at all stages of the river.

During the last year work has been in progress at Pine Tree Rapids, 35 miles above the mouth of the Snake River, removing rocks from the channel, by which it was greatly improved at that point.

It is the opinion of the engineer officer in charge of the improvement of these rivers that the Snake River can be rendered navigable at all seasons of the year, as far as Lewiston, by light-draught steamers, when navigation is not interrupted by ice, for the sum of $100,000, and that the channel of the Columbia River, between the mouth of the Snake River and Celilo, could be greatly improved for the sum of about $50,000.

Admitting these opinions to be correct, it follows that for the sum of about $150,000 the navigation from Celilo, on the Columbia River, to Lewiston, on the Snake River, a distance of about 260 miles, may be rendered practicable for light-draught steamers throughout the year, except when it is obstructed by ice.

The object of the proposed improvements of the Upper Columbia and Lower Snake rivers from the Cascades to Lewiston is to obtain continuous and uninterrupted navigation from the latter place to the sea, a distance of about 500 miles, so that the products of the great grain-growing country in the vicinity of these rivers may be brought to a market.

This region, more particularly in the vicinity of Walla Walla and on the Snake River, is rapidly being settled. The products are increasing from year to year, and the impediments to navigation in the Snake and Columbia Rivers are all that prevent the country from becoming rich and prosperous.

We have already seen that the improvement of the Snake River below Lewiston and of the Columbia River between the mouth of the Snake and Celilo are comparatively inexpensive, involving an expenditure of about $150,000. Such is not the case, however, when we come to consider the subject of canals around the two great barriers in the Columbia River, at the Cascades, and at The Dalles. Canals around these falls will necessarily be expensive, involving some millions of dollars.

We have already estimated that the cost of the complete canal around the Cascades will be $2,544,545. That around the falls and rapids at The Dalles will probably be even more expensive. Each of these canals may be regarded as the complement of the other. If one of them is necessary, the other is also equally necessary; it will make but little difference, in the way of economy of transportation, which of them shall be first constructed. Either of them connects the stretch of the Columbia between the two great barriers with the river either above or below; the Cascades Canal joining this section to the Lower Columbia, and The Dalles Canal connecting it with the river above.

And here we may remark that the country along this portion of the river, between the Cascades and The Dalles, is mostly precipitous mountains. It is sparsely inhabited, and must always remain so. The productions are small. With the exception of those from the valley of Hood River and a few smaller valleys, they may be said to amount to a mere trifle.

It follows, therefore, that the construction of a canal around the Cascades or at The Dalles could not be justified for any benefit either could confer on the mountainous district between these two places. It is the great grain-producing country, as said before, on the Upper Columbia and Snake Rivers that is to be opened to settlement by the construction of these two canals, affording, as they will when completed, uninterrupted water communication to the sea.

It may be remarked that the construction of one of these canals without the other will be of very little advantage to the country or to commerce in the existing state of things. This arises from the circumstance that the whole of the navigation of the Upper Columbia and Snake Rivers is now in the hands of a single company. It owns all the steamers on the waters just mentioned, and has railroad portages around the Cascades and at The Dalles, or between The Dalles and Celilo. All freight has to be handled twice at each of these places.

Now, if the Government of the United States builds a canal around the Cascades, it must, under this state of things, inure to the benefit of that company, for it will do away with the necessity of the lower railroad portage. It will not follow, however, as a logical consequence, that the cost of transportation between the country to be most benefited and the sea will be lessened by this canal alone; for, although one of the gates now closing the navigation of the river would thereby be opened, this company, without a canal at The Dalles, would still hold the keys of the other barrier, and it might, and possibly would, charge as much for transportation over this one portage as long as it was able to control it as it heretofore has over the two.

The only way to throw the entire river open to competitive navigation will be by the construction of a canal at The Dalles as well as at the Cascades.

The navigation of the river would then be free to any company or individual, with the exception of the necessary tolls to support and maintain the two canals.

In view of the foregoing considerations, and in order to enlighten the department as to the proper plan and cost of a canal at The Dalles, and inform Congress and the country on the subject, the Board recommends that an appropriation of $10,000 be asked at the next session of Congress for a survey of the Columbia River between the town of The Dalles and Celilo and for a plan of a canal between these two places.

Respectfully submitted.

B. S. ALEXANDER,
Lieutenant-Colonel of Engineers, President of Board.
C. SEAFORTH STEWART,
Lieutenant-Colonel of Engineers.
R. S. WILLIAMSON,
Lieutenant-Colonel Corps of Engineers.
G. H. MENDELL,
Major of Engineers.
JOHN M. WILSON,
Major of Engineers.
A. H. PAYSON,
First Lieutenant of Engineers, Recorder

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

APPENDIX KK.

ANNUAL REPORTS OF LIEUTENANT-COLONEL THOMAS LINCOLN CASEY, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1878.

K K I.

PUBLIC BUILDINGS AND GROUNDS IN THE DISTRICT OF COLUMBIA.

OFFICE OF PUBLIC BUILDINGS AND GROUNDS,
Washington, D. C., June 30, 1878.

GENERAL: The public grounds in the city of Washington comprise some two hundred and seventy pieces of land, ranging in size from less than a thousand square feet to tracts of 50 acres in extent. Of these reservations a sufficient number have been graded, sodded, planted with trees and shrubs, intersected with roads and paths, supplied with water and gas, &c., to create some 200 acres of ornamented grounds, which, for at least eight months in the year, need constant attention and care. To the extent the appropriations would permit, all the care and labor possible have been bestowed upon these improved reservations during the past year. The work upon the squares consists in frequent mowing of the lawns, removing weeds, scuffling, raking, rolling, and sweeping the paths, trimming edges and borders of grass-plats, and trimming and staking trees and shrubs. To do this work as frequently as is demanded for the best appearance of the grounds will require not less than 60 men for eight months, from March 1 to November 1, and 23 men for four months, from November 1 to March 1.

In Lafayette Square during the past year additional tile-drains and water-catches have been put in along the sides of some of the paths, but the catches are not yet in sufficient number to prevent the washing of the gravel into Pennsylvania avenue during heavy rain-storms; other catches must be added to remedy this serious defect in the drainage of this square. The lawns were dressed during the winter with a rich compost, which has materially improved the grasses, and many bare spots on the shaded portions of the grounds have been brought back into turf. The lodge has been painted and put in thorough order, and new gutters and drain-spouts added to the building, which has also been painted.

The improvements in Franklin Square have consisted in repairs of the basin of the fountain and the introduction of six additional gas-burners.

In McPherson Square quite a number of deciduous trees and evergreens have been planted in such a manner as to break up the open spaces in the grounds formerly the site of Vermont avenue, and still so disposed as not to mask the view of the bronze statue from positions upon that street. This square would be greatly improved by breaking the straight and stiff rows of trees and paths into more graceful lines.

During the year the remains of the old jail in the northeastern corner of Judiciary Square were removed, as well as a large pile of dirt left over from the early improvements of these grounds. The ground was then soiled and sowed, and, when consolidated, paths were laid out, excavated, and filled with the old bricks taken from the foundation of the jail, on which fine gravel was well rolled down. Three lamp-posts were set up in this part of the ground, the post-and-chain fence completed, and the grounds planted with evergreens and deciduous trees to correspond to the portions of the square already improved. A fountain with a white marble bowl 25 feet in diameter was erected in the center of the square, and a large number of seats placed along the paths. Means were taken to prevent the use of the broad path running north and south by carriages, as this path was intended for pedestrians. The north front of the city-hall building was planted with climbing vines that will cover the unsightly wall in a few years. Extensive repairs were put upon the lodge and the plumbing within it.

CIRCLE AT FOURTEENTH AND M STREETS NORTHWEST AND PEDESTAL OF STATUE OF GENERAL GEORGE H. THOMAS.

This reservation was selected as the site of the equestrian statue of Maj. Gen. George H. Thomas by the committee designated in the act of July 31, 1876, chap. 246. The design for the pedestal was made by Smithmyer & Co., of this city, and was selected from among a number of designs by other artists, by the managing committee of the Army of the Cumberland acting in conjunction with the members of the committee for selecting the site.

Work was commenced upon the foundation of the pedestal in August of 1877, and in order to obtain a secure base it was necessary to turn the Fourteenth-street sewer, carrying it some 50 feet to the eastward, and returning it into the old sewer again below the circle. The cut granite was obtained by contract from M. K. Chase, of Blue Hill, Me., and the bronze lamp-posts from Wilhelm & Neumann, of Philadelphia. The grounds around the pedestal have been improved in a temporary way, and a light wire fence run around the circle to prevent its being crossed by foot-passengers. Some evergreens and low deciduous trees have been planted, and a few beds of coleus and geraniums set out.

It is recommended that the sidewalk be increased in width 5 feet upon its inner edge, and that a neat curb of cut granite, with suitable inside drains, be constructed around the circle. This will bring the point of sight of the statue when erected at about the proper distance from it.

The construction and erection of the statue itself is not in the hands of the general government, but in charge of the Society of the Army of the Cumberland.

IOWA CIRCLE.

[At the intersection of Vermont avenue and P street, formerly known as Thirteenth Street Circle.]

During the past summer a number of evergreens and deciduous trees from the Fourteenth and M street circle were transplanted into this reservation, and the bowl of the fountain, which from its great depth and low curb was dangerous to children, was filled with stone and gravel, so that the water in the bowl could not be over 18 inches in depth.

A small reservation between Vermont avenue, Thirteenth, and O streets was cut down to grade, soiled and sodded, supplied with water and overflow pipes for a fountain, and planted with evergreens and flowering shrubs.

The improvement of this reservation, as well as the one between Rhode Island avenue, P and Twelfth streets, will be completed the coming year.

FARRAGUT SQUARE.

One of the asphalt paths of this square was resurfaced during the year by Cranford & Hoffman, as a sample of their work, and without cost to the United States. The roadway through this square in the prolongation of Connecticut avenue should be removed.

GROUNDS SOUTH OF THE EXECUTIVE MANSION.

This reservation, known as the White Lot, has been filled to within about 3 feet of grade, over a large portion of its surface, the sunken parts being along Seventeenth street. A plan of improvement after the project of Downing and as approved by President Fillmore was commenced during the year. It consists substantially of a large field or parade some 17 acres in extent, and elliptical in shape, which will occupy the center of the reservation, the remaining portions of the ground being reserved for foliage trees and shrubs, and shaded walks and drives. During the past year some 250 feet in depth of the upper part of the parade was graded, sodded, and brought into grass-land. The construction of the parade will be continued the coming year. Several improvements upon the grounds near the Executive Mansion have been made, the principal ones being the construction of a number of beds for flowering and foliage plants, and the removal of the small fountain and dilapidated music-stand in the center of the south lawn. A new hot-house and some forcing-frames were constructed during the year, and extensive repairs put upon the conservatory and old hot-house buildings. These buildings are, however, in such a damaged condition it will hardly be possible to patch them up much longer. They should be replaced by buildings having light iron frames, the sash and glazed portions being of wood.

MONUMENT GROUNDS.

Appropriations having been made during the past winter for the purpose of modifying the ponds in this reservation for the culture of carp, under the direction of the United States Commissioner of Fish and Fisheries, the work was commenced in February and completed the latter part of June. These small lakes are drained through a culvert which empties into the North B street sewer, and the work consisted mainly in so arranging the bottoms of the ponds that the water can be drained off rapidly, excepting so much as may be necessary to fill receiving basins located at the sluice-gates. These were built with two sets of stop-planks, in front of which are galvanized iron wire screens, to prevent the exit of fish from the ponds, and the introduction of other species from the river. The water-ways are so proportioned that a sufficient supply to fill the culvert will pass through them, notwithstanding the obstruction of these screens. The bottom of the east lake was quickly graded, but in the west lake it was necessary to fill the prism of the old canal, which had been left in the bottom of the lake when originally constructed, and to cut down some portions of the old tow-path still remaining. A 12-inch cast-iron pipe, provided with screens at each end and a valve in the center, was laid to connect the east and west lakes. The island in the west lake was diked around its margin by a dike 6 feet in width and 3 feet high, and the outer face of the dike was paved with cobble-stones to prevent washing. Upon the top of this island two hatching ponds of 2,500 square feet each in area were constructed; these were carefully graded upon the bottom, supplied with collecting basins and drain-pipes, and thickly planted with aquatic plants. A 2-inch water-pipe was carried from the north side of the east lake over and upon the island to supply these ponds with water. A rustic bridge was built to connect the island with the roadway between the lakes and a small rustic watch-box built near the hatching ponds for the service of the attendants. The western end of the west lake along Virginia avenue was filled to a line with the eastern side of that street, and the unimproved portions of the bank of this lake along Virginia avenue and north B street properly sloped, revetted with cobble-stones, and sodded.

During the year an additional propagating-house, 140 feet long by 10 feet wide, was put up at the nursery, and the stock of trees and flowering shrubs materially increased from cuttings and seeds.

Two thousand six hundred and fifty-eight deciduous trees, evergreens, and shrubs were purchased and set out during the year, 1,274 being put in the reservations and the remainder in the nursery.

Every iron fence needing repairs was put in thorough order, and with the exception of two or three fences painted late last year, each fence either in the fall or spring received a coat of paint.

A compost-bed, containing some 2,500 loads of muck, was made last fall, and spread during the winter upon Lafayette Square, Executive Mansion grounds, and McPherson Square; 22 tons of bone-dust were spread upon the grass lawns of the reservations east of the Capitol; 40 new seats were placed in the several reservations, and a number of the old ones repaired and refastened to the ground.

The title of the United States to lots 13 and 14, square 959, was established, and these lots were graded and filled to the level of the sidewalk, removing a stagnant pool of water of great injury to the people living in its vicinity.

The 17 ornamental fountains and all the drinking fountains were carefully repaired and kept running, except during the freezing weather in the winter.

Upon the water-pipes used to bring the spring-water to the Capitol an extensive break on North Capitol street was repaired, requiring the relaying of some 250 feet of 4-inch pipe. A new stop-valve was introduced at the corner of Boundary and North Capitol streets, and a brick house, with a brick domed roof and iron doors, constructed over the spring supplying the Capitol.

At the Executive Mansion the necessary repairs upon its roof, windows, doors, water-pipes, cisterns, and heating apparatus were applied. The private dining-room was entirely refitted, the ceiling frescoed and walls repapered. A new staircase was constructed from the corridor of the first floor to the basement, and the old one closed up. A flag-staff was erected over the southern portico, and the necessary repairs made upon the furniture and fittings of the house.

The main requirement upon the public grounds of the city is a force of laborers sufficient to keep them in order. Lying as they do, in detached parcels, a larger force is needed for their care than would be necessary if the grounds were in one tract only. The time consumed in passing from one reservation to another is considerable, and the lack of proper supervision over the force when scattered, increases the cost of the work. Each reservation containing either a piece of statuary, a lodge, a fountain, ornamental vases, and drinking fountains requires a watchman, not only to preserve this property from injury, but to make minor repairs of the walks and sodding, to keep the paths and lawns free of papers and shavings and other rubbish dropped or blown upon the grass and shrubbery, and also to preserve order among and protect those who may chance to visit the squares for their personal pleasure and comfort. In many of the squares a larger number of settees is needed.

A number of the reservations not now improved should speedily be put in order. This is especially true of several east of the Capitol, particularly Stanton Place on Maryland avenue between Fourth and Sixth streets; North Carolina avenue between Second and Third streets; South Carolina avenue between Fourth and Sixth streets, and several triangular reservations lying along those avenues. Stanton Place has recently been selected as the site of a fine equestrian statue of General Green of the Revolutionary Army, and the preservation of the foundation of the pedestal seems to require that an appropriation should be made for its security. The reservations between Third, Fourth-and-a-half, Sixth, and Seventh streets can be made quite as attractive as the Smithsonian and Agricultural Grounds, and that, too, at a reasonable cost.

ESTIMATE OF AMOUNTS REQUIRED FOR THE FISCAL YEAR ENDING JUNE 30, 1880.

Salaries of employés, &c., public buildings and grounds, under Chief of Engineers:		
1 clerk	$1,600	
1 messenger	840	
Rent of office	900	
1 public gardener	1,800	
1 foreman and laborers employed on the public grounds	26,000	
2 drawkeepers at the navy-yard and upper bridges	1,440	
1 watchman at Franklin Square	660	
1 watchman at Lafayette Square	660	
4 watchmen in Smithsonian grounds, at $660 each	2,640	
1 watchman at Judiciary Square	660	
1 watchman at Lincoln Square	660	
1 watchman for Iowa Circle	660	
1 watchman for Rawlings Square	660	
1 watchman for McPherson and Farragut Squares	660	
1 watchman for Washington Circle and neighboring reservations	660	
1 watchman for Fourteenth-street Circle and neighboring reservations	660	
1 bridge-keeper at Chain Bridge	660	
Contingent expenses	500	
		$42,320
Improvement and care of public buildings and grounds in and around Washington:		
Filling in and improving grounds south of Executive Mansion	10,000	
Ordinary care of green-houses and the nursery	1,500	
Ordinary care of Lafayette Square	1,000	
Ordinary care of Smithsonian grounds	5,000	
Care and improvement of reservation No. 3 (Monument grounds)	1,000	
Annual repair of iron fences	500	
Manure and hauling the same	5,000	
Painting iron fences, vases, lamps and lamp-posts	1,500	
Purchase and repairs of seats	1,000	
Purchase and repair of tools	1,000	
Trees, tree-stakes, lime, white-washing and stock for nursery	4,000	
Removing snow and ice	1,000	
Flowers, pots, twine, baskets and lycopodium	1,000	
Care and construction and repair of fountains in the public grounds	2,500	
Improving Stanton Place	6,000	
Continuing improvement of Seward Place	3,000	
Abating nuisances	500	
Improving reservation on South Carolina avenue between Fourth and Sixth streets east	5,000	
Improving reservation on North Carolina avenue between Second and Third streets east	3,000	
Improving various reservations	15,000	
Improving reservation Massachusetts and New Jersey avenues	3,000	
Improving circle at Fourteenth street and Massachusetts avenue	5,000	
Paving with asphaltum roadway in front of Executive Mansion	8,000	
		84,500

Care of and repairs, fuel, &c., Executive Mansion:

Care and repairs of Executive Mansion	*$10,000	
Refurnishing Executive Mansion	10,000	
Fuel for the Executive Mansion and the green-houses	3,000	
Care and necessary repairs of the green-houses	6,000	
		$29,000

Care and repair of bridges:

Ordinary care of Bennings, Anacostia and Chain bridges, including fuel, oil, lamps, matches, &c	1,200	
Replanking and painting Chain Bridge	2,500	
Repairs upon Bennings Bridge and its carriage-ways	2,500	
Raising embankments of Anacostia Bridge and riprapping piers and abutments	3,000	
		9,200

Lighting the Executive Mansion and the public grounds:

Gas, pay of lamp-lighters, gas-fitters, plumbers, plumbing, lamps, lamp-posts, matches, and repairs of all kinds, fuel for office, watchmen's lodges, and for the greenhouses in the nursery	18,000

Repair of water-pipes and fire-plugs:

Repairing and extending water-pipes, purchase of apparatus to clean them, and for cleaning the springs and repairing and renewing the pipes of the same that supply the Capitol, the Executive Mansion, the War and Navy Departments	3,000

Telegraph to connect the Capitol with the Departments and Government Printing Office:

For repair and care of the same	1,500

Financial statement, fiscal year ending June 30, 1878.

Title of appropriations.	Amounts available at beginning of fiscal year.	Amounts expended.
Improvement and care of public grounds	$21,500 00	$20,630 28
Improvement and care of Judiciary Square	1,974 67	1,974 30
Repairs, fuel, &c., Executive Mansion	20,000 00	19,965 87
Lighting, &c., Executive Mansion, &c., 1878	15,000 00	14,721 32
Repairs of water-pipes and fire-plugs	4,000 00	2,614 67
Repairs of Navy-yard and Upper bridges	1,000 00	748 88
Contingent expenses public buildings and grounds	500 00	499 61
Salaries of employés public buildings and grounds	30,804 00	30,680 56
Pedestal for the statue of General George H. Thomas	24,744 30	16,632 95
Telegraph to connect the Capitol with departments, &c	500 00	497 48
Adapting ponds in Monument Lot to culture of carp, &c. (act December 15, 1877)	7,200 00	7,076 33
Salaries of employés public buildings and grounds (act December 15, 1877)	844 77	844 77
Lighting, &c., Executive Mansion, &c. (act December 15, 1877)	130 23	130 23
Repairs of Navy-yard and Upper bridges (act December 15, 1877)	75 00	75 00

Very respectfully, your obedient servant,

THOS. LINCOLN CASEY,
Lieutenant-Colonel of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

K K 2.

WASHINGTON AQUEDUCT.

OFFICE OF WASHINGTON AQUEDUCT,
Georgetown, D. C., July 31, 1878.

GENERAL: I have the honor to submit the following report of operations upon the Washington Aqueduct for the fiscal year ending June 30, 1878.

On the 3d of March, 1877, an appropriation was made by Congress, as follows:

For engineering, maintenance, and repairs	$15,000 00

In July, 1877, the work done was limited to the supervision of the distribution of Potomac water in the conduits, reservoirs, and pipes.

In August the embankments over the pipe-line and conduit were thoroughly repaired, and the ditches were cleaned out. At Foundry Branch the iron mains were covered with clay, and further protected from the freshets of the branch with a stone pavement. At Great Falls, as soon as the water in the river had fallen below the crest of the dam, the ripraps, which had formed a part of the backing, and which had been carried over the dam by the spring freshets, were replaced.

Considerable damage was done to the conduit embankments by the heavy rainfall of July 28 and 29, and they were repaired during the month.

In September, large bowlders were broken and removed from the upper end of culvert No. 25. At culvert No. 23, sand and gravel were removed from the interior, and the bed of the stream leading therefrom was cleaned out and deepened.

In October, at Foundry Branch, a freshet uncovered the iron mains, and carried away a part of the overfall. The mains were recovered, and the overfall was repaired. The slopes of the embankments over the pipe-line were damaged by heavy rains, and were repaired. A leak in the 36-inch main near the distributing reservoir was also repaired. The embankment east of the auxiliary gate-house was widened 2 feet for a distance of 100 feet. The embankment around the stair-well-house, having been badly washed, was refilled with clay. The guard-ditch on the east dam of the distributing reservoir, the long ditch along the north side of the distributing reservoir, and the ditch above the influent gate-house, were cleaned out.

At culverts Nos. 25 and 26 the ditches were cleaned out and the material excavated therefrom was used in repairing the embankment at waste-weir No. 3. Between culverts Nos. 23 and 24, 24 and 25, rain-water from the hillsides flowed over the conduit road, and carried away a part of the embankments, which were repaired.

At the receiving reservoir the road leading from the conduit road to the gate-keeper's dwelling was put in good order. The ditches at this point were cleaned out and the material excavated therefrom was used in repairing the reservoir dam.

The footwalk in the tunnel leading to waste-weir No. 2 was carried away by a flood from the receiving reservoir and was replaced.

A wooden bridge over Powder Mill Branch at the upper end of the receiving reservoir was washed from its abutments and carried to the upper end of Dalecarlia tunnel. It was towed back, taken apart, and replaced. The approaches to this bridge were repaired. Between the receiving reservoir and Great Falls the slopes of the embankments, where damaged, were refilled; ditches were cleaned out, and the roadway over the conduit, and the road leading from the conduit to Great Falls were repaired.

In November the sidewalks of Rock Creek bridge were repaired. Near the distributing reservoir a leak occurred in the 30-inch main, which at that point is 15 feet below the surface, and it was necessary to shut off the water from the distributing reservoir to Foundry Branch.

After uncovering the pipe it was ascertained that its lead joint was partly forced out; it was recalked and secured with a wrought-iron band and set-screws. In front of the distributing reservoir the ditches were cleaned. At waste-weir No. 3 a road culvert was repaired.

A part of the plank walk in the tunnel leading to waste-weir No. 2 was carried out by a freshet from Powder Mill Branch, which raised the surface of the receiving reservoir to a height that overflowed the river.

The planks were brought back and the walk repaired. Between the receiving reservoir and Great Falls embankment slopes were repaired where they had been damaged by rain.

From November 24 to November 29 there was a freshet in the Potomac River, and the water at Great Falls rose to the height of 160 feet above the datum of the Washington Aqueduct, or 12 feet above the crest of the Potomac dam.

At the same time, the Chesapeake and Ohio Canal overflowed its banks immediately over the feeder of the Washington Aqueduct, and 75 feet of the towing-path was carried away.

The masonry forming the arch of the feeder was uncovered from a point near the middle of the canal to the mouth of the feeder, a distance of 150 feet. The chamber at the head of the aqueduct was filled with stones that had formed the slope-wall of the canal, and the aqueduct feeder for a distance of 300 feet was filled with *débris* to depths varying from 3 to 6 feet, so as to entirely stop the flow of water during the ordinary low stages of the river. The stop-planks were nearly all broken and carried away by the current.

In December, as soon as the freshet had subsided, repairs were commenced. A sufficient quantity of square timber was obtained from an island in the river, and a new set of stop-planks were made therefrom. An earthen dam was built across the prism of the Chesapeake and Ohio Canal immediately below its waste-weir, which was then cleaned out so that the water flowing in the canal could pass into the river.

The water over the arch of the aqueduct feeder was bailed out, the arch was thoroughly examined, and the masonry, having sustained no damage was covered with clay-puddle from 2 to 4 feet in depth. The tow-path of the canal was rebuilt with clay to a height of 4 feet above the bottom of the canal. This much was necessary to protect the filling over the feeder arch from any waste water in the canal. The chamber at the head of the aqueduct was cleaned out to a depth sufficient to put in the stop-planks, the river was shut off from the feeder, the water was drawn therefrom, and it was partly cleaned out to a depth sufficient to permit the feeder to supply the conduit with water.

The Potomac dam sustained but little damage; some of its ripraps were carried away by the freshet, and a part of them were replaced.

Between Great Falls and the receiving reservoir several of the embankments were repaired where they had been washed by the rain.

While the river was shut off from the aqueduct the supply of water for Georgetown and Washington was drawn from the receiving and distributing reservoirs, the surfaces of which were lowered from + 145.00 to + 142.50, or 2½ feet over a surface of 96 acres.

In January the footwalk in the tunnel leading to waste-weir No. 2 was repaired. The ditches at culvert No. 26 and those along the pipe-line were cleaned out.

Snow and ice were removed in Georgetown in front of government property on Road, High, and Aqueduct streets.

In February and March, between the receiving and distributing reservoirs, repairs were made to the conduit road and to the road over the pipe-line.

In April, at Great Falls, a temporary dam was built in the river immediately above the basin at the head of the aqueduct, the water was drawn from the feeder, and the basin was cleaned out preparatory to cleaning out the feeder leading to the gate-house. The work was stopped on the 27th of April in consequence of high-water in the river.

Between Great Falls and the junction the roadway was repaired and in a few places widened.

Between the junction and receiving reservoir the ditches were opened, the embankments repaired, and the channels of several culverts were cleaned out. Between the receiving and distributing reservoirs the ditches were opened and the embankment over culvert No. 24 was widened. At the distributing reservoir the embankment slopes were repaired, ditches opened, and a part of the fence was whitewashed. The macadam road over the conduit and pipe-line was repaired.

In May, at Great Falls, the water was drawn from the aqueduct, and the feeder from the river to the gate-house was thoroughly cleaned; the *débris* that was removed therefrom was dumped into the river below the dam.

Between Great Falls and receiving reservoir embankments were repaired and ditches opened. A new channel was excavated for the stream under Griffith Park Bridge, and the foot of the embankment at this point was protected with ripraps.

At the receiving reservoir a new derrick was erected at the north stop-plank chamber, and the derrick at the south chamber was repaired. Between the receiving and distributing reservoirs the ditches were cleaned out. At culvert No. 23 the bushes were cut from the stream above the culvert, and the channel of the stream below it was deepened. This culvert was cleaned out from end to end, it having been choked up with gravel and *débris*.

At the distributing reservoir the whitewashing of fences was finished. Each of the gate-houses was whitewashed inside. The pipe-vaults at distributing reservoir, Foundry Branch, and Georgetown were whitewashed, and the stopcocks on the 12, 30, and 36 inch mains were cleaned, oiled, and put in good working order.

At the high service reservoir, Georgetown, the wooden fences were whitewashed. The gallery under the reservoir was thoroughly cleaned and whitewashed. The telegraph-poles were also whitewashed.

In June, at Great Falls, the fences surrounding the government lands were whitewashed. Near Cabin John Bridge the telegraph-line was repaired. At the receiving reservoir repairs were made to the stop-plank grooves; the wooden bridge over the waste channel and a part of the fences were whitewashed. At culvert No. 24 the embankment was repaired. At the distributing reservoir a retaining-wall was built on the north side of the road near the auxiliary gate-house, the floor of Rock Creek Bridge was repaired, and a number of the stopcock vaults in Washington were cleaned and whitewashed.

During the year the government lands at Great Falls, distributing reservoir, and Georgetown were kept in good order, and the general distribution of Potomac water in the conduits, reservoirs, and pipe-lines was properly attended to. The government mains were often flushed, and great care was taken to supply them with the clearest water.

On June 28 the conduit was shut off from the distributing reservoir, and remained shut off for 24 consecutive hours. The elevation of the water-surface of the reservoir was recorded each hour, and the quantity of water drawn from the reservoir during the 24 hours was as follows:

	Gallons.
From 6 a. m. to 9 a. m	3,493,437
From 9 a. m. to 12 m	3,488,014
From 12 m. to 3 p. m	3,204,185
From 3 p. m. to 6 p. m	3,199,592
From 6 p. m. to 9 p. m	3,195,006
From 9 p. m. to midnight	2,913,168
From midnight to 3 a. m	2,632,429
From 3 a. m. to 6 a. m	2,760,114
Total quantity	24,885,945

The estimates for which appropriations should be made for the next fiscal year are as follows:

For engineering, maintenance, and general repairs	$20,000
For commencing the construction of the dam, at Great Falls, across the Virginia channel of the Potomac	50,000
For improving grounds around gatekeeper's dwelling at the receiving reservoir	1,000
For building wooden fence around the government land at the receiving reservoir	7,000
For soiling, sodding, and seeding the embankment and excavation slopes of the distributing reservoir and conduit	15,000
For building a wrought-iron truss-bridge over the waste channel at the receiving reservoir	11,000
For building an overfall over the connecting conduit for the waste-channel of the receiving reservoir	2,000
For continuing the macadamizing of the conduit road	10,000
Total	116,000

The following is a financial statement for the fiscal year ending June 30, 1878:

Act of March 3, 1877.

For engineering, maintenance, and repairs:

Available July 1, 1877	$15,000
Expended in 1877 and 1878	15,000

The Potomac dam at Great Falls remains in an unfinished condition. No work, except slight repairs, has been done upon it since December, 1867. It should be built entirely across the river to the Virginia shore. The consumption of Potomac water for several years past has amounted to more than the minimum flow of the Maryland channel. Before the supply can be increased during the summer months it will be necessary to finish the Potomac dam and to lay additional mains from the distributing reservoir into Washington.

The conduit road is macadamized from the distributing reservoir to culvert No. 6. The remainder of the road should also be macadamized.

The embankment and excavation slopes of the conduit and pipe-line, and the embankment-slopes of the distributing reservoir should be protected with sods, or soiled and seeded with grass.

The government lands at the receiving reservoir should be protected with a substantial wooden fence. The grounds surrounding the gatekeeper's dwelling should be improved by grading and tree-planting. Powder-Mill Branch, which empties into the receiving reservoir, is liable to sudden freshets; at times the waters have risen beyond the control of the gatekeeper and caused considerable damage by overflowing the conduit at the waste-channel and waste-weirs Nos. 2 and 3. A stone overfall should be built over the connecting-conduit, across the waste-channel, for the passage of the storm waters.

The wooden bridge over the waste-channel was built in 1863. Its timbers are old and decayed; it should be removed and a wrought-iron truss-bridge should be erected in its place.

Very respectfully, your obedient servant,

THOS. LINCOLN CASEY,
Lieutenant-Colonel of Engineers.

The CHIEF OF ENGINEERS, *U. S. A.*

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